SECOND EDITION

ENGINEERING MANAGEMENT

Meeting the Global Challenges

C. M. Chang

CRC Press
Taylor & Francis Group

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Meeting the Global Challenges

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Dedicated to my loving family, wife Birdie Shiao-Ching, son Andrew Liang Ping, son Nelson Liang An, daughter-in-law Michele Min Xiu, grandson Spencer Bo-Jun, and granddaughter Evya Bo-Ting.

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Contents

Section III Engineering Leadership in the New Millennium

Preface to the Second Edition

This second edition of *Engineering Management: Meeting the Global Challenges* is written for senior and first-year graduate engineering students majoring in disciplines such as aerospace, biomedical, chemical, computer, electrical, mechanical, industrial, and system engineering, as well as other technical domains (i.e., science, technology, and mathematics). It may also be used as a self-study guide by engineering professionals who aspire to become managers. It should be of value as well to first-line engineering supervisors/managers in further advancing their careers along the managerial career path. This target group of students and young professionals form the group the author defines "science, technology, engineering, and math (STEM) professionals and managers."

The rapidly changing environment of today's global economy calls for workers who are capable of holistic thinking, balancing analysis and intuition, living with ambiguity, and practicing strategic flexibility. Changes noted in the marketplace include (1) Internet-based communication, delivery, and business transactions; (2) customer references and buying habits; (3) new technologies related to data processing; (4) business alliances on a global basis; and (5) heightened competition in industry. These changes will require that STEM professionals and managers be more appropriately prepared than otherwise. This second edition is designed to address these needs.

The first edition of *Engineering Management: Challenges in the New Millennium* was well received in the marketplace. It was translated into Korean and awarded the Best Book of the Year Award in 2007 by the International Association for Management of Technology. At one point, it was adopted by about 20 U.S. and international educational institutions.

This second edition refocuses on the new strategy for STEM professionals and managers to meet the global challenges through the creation of strategic differentiation and operational excellence. Thus, major revisions contained in this second edition include: (1) a new chapter on creativity and innovation, (2) a new chapter on operational excellence, and (3) a combination of the chapters on financial accounting and financial management.

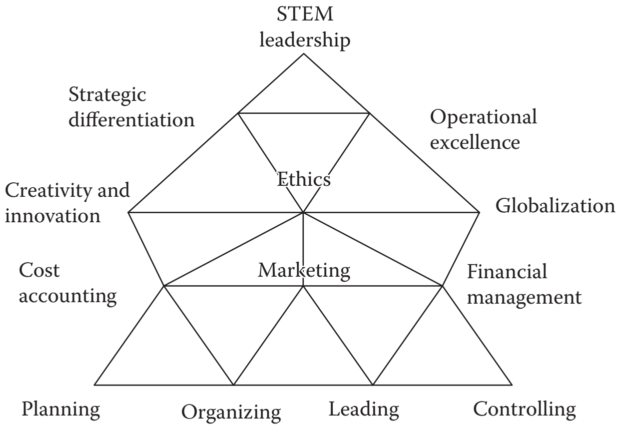
Strategic differentiation is essential for any enterprise to introduce and maintain market competitiveness in the form of differentiable product/service packages. STEM professionals and managers need to become well versed in creating product/service innovations that are both desired and required by customers. Specific thinking strategy, such as DeepThink discussed in Chapter 12, could be beneficially practiced. The chapter on creativity and innovation is to encourage STEM professionals and managers to actively pursue the development of novel products/services in order to add significant value in creating strategic differentiation in their enterprises.

STEM professionals and managers need also to focus on creating operational excellence, which addresses issues related to process efficiency, cost reduction, time to market, and doing all things well in order to improve the short-term profitability of their enterprise. New Internet-based enablers such as big data, analytics, and cloud computing are becoming available for STEM professionals and managers to apply. The new chapter on operational excellence illustrates the effective use of many such productivity-enhancing tools.

STEM professionals and managers need to acquire background knowledge in financial accounting and management, as such knowledge promotes better decision-making related to the enterprise and fosters the development of companywide initiatives.

The key book design strategy for this second edition covers three distinctive sections: (1) engineering management fundamentals, (2) business management skills, and (3) leadership essentials, to ready STEM professionals and managers for meeting the global challenges. Such a broad-based background is viewed as essential for STEM professionals and managers to exert a strong leadership role in the dynamic and challenging marketplace.

The following "three-decker leadership architecture" forms the design basis of this book.



A large number of engineering and business cases are contained in the text-end appendix. These cases cover various management and business issues in diversified sectors. They represent a useful extension of the exercise problems listed at the end of each chapter.

All STEM professionals and managers face global challenges that have six dimensions. These are (1) inside, (2) outside, (3) present, (4) future, (5) local, and (6) global.

Manage/Lead/Act/Think	Focuses
Inside	Core competencies, cost and quality control, production and process excellence
Outside	Emerging technologies, supply chains, market orientation, customer relationship
Today	Implement all projects to achieve operational excellence, do the thing right
Tomorrow	Apply creativity and innovation, do the right things, and lead in creating strategic differentiation
Local	Build local strengths, unique partnerships, implement local adjustments and customization
Global	Global resources, global scale and scope, global mind-set, global partnerships, and savvy

In summary, this book aims at equipping STEM professionals and managers with the necessary knowledge and skills to achieve strategic differentiation and operational excellence in order to meet the aforementioned six-dimensional global challenges.

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Preface to the First Edition

Engineers with excellent managerial skills and superior business acumen are needed to lead the Corporate America in the new century. As the economy grows increasingly global, technologies advance at faster pace, and marketplace becomes more dynamic in the decades ahead, many industrial companies will need technically trained engineers to turn technological innovations into profitability.

The need for engineering management training is obvious from another point of view. National Science Foundation estimated in 2000 that about 46% of U.S. engineers and scientists were actively working in managerial/administrative capacities. This managerial percentage remained more or less constant across the age groups from below 35 to more than 55. As this trend continues, almost one out of every two engineers/scientists will be engaged in managing people, projects, teams, and technology and other resources to create value for their employers.

This book prepares engineers to fulfill their managerial responsibilities, acquire useful business perspectives, and take on the much-needed leadership roles to meet the challenges in the new millennium.

A number of themes permeate the book. Value addition, customer focus and business perspectives are emphasized throughout. Also underlined are discussions of leadership attributes, steps to acquire these attributes, the areas engineering managers are expected to add value, the web-based tools which can be aggressively applied to develop and sustain competitive advantages, the vital tasks of e-transformation, the opportunities offered by market expansion into global regions, and the preparations required for engineering manager to become global leaders.

The book is intended for senior and first-year graduate engineering students majoring in disciplines such as aerospace, biomedical, chemical, computer, electrical, mechanical, industrial and systems engineering. It may also be used as a self-study guide by engineering professionals who aspire to become managers. It should be of value to first-time engineering supervisors/managers interested in further advancing their careers along the managerial career path as well.

The book is organized to contain three major sections: I. Functions of Engineering Management, II. Business Fundamentals for Engineering Managers, and III. Engineering Management in the New Millennium.

Section I discusses the basic functions of engineering management such as planning, organizing, leading and controlling. These functions provide engineers and engineering managers with foundation skills to manage themselves, staff, teams, projects, technologies and global issues of importance.

Best practices are emphasized as pertinent standards for goal setting and performance measurement. Engineering managers solve problems and minimize conflicts to achieve the company's objectives. They make rational decisions and take lawful and ethical actions. They apply Monte Carlo methods to assess projects involving risks and uncertainties. They engage emerging technologies, motivate a professional workforce of diversified backgrounds, develop new generations of products/services in a timely manner, and constantly surpass the best practices in industry.

The roles of engineering managers in strategic planning, employee selection, team building, delegating, decision-making and in the management of creativity and innovations are explained. The development of managerial competencies is emphasized.

Section II covers the fundamentals of engineering management including cost accounting, financial accounting/analysis, managerial finance, and marketing management. This section is to enable engineers and engineering managers to acquire a broadened perspective with respect to the business and stakeholders of the company and to facilitate their interaction with peer groups/units.

It also prepares engineering managers to make decisions related to cost, finance, products, services and capital budgets. Discount cash flow and internal rate of return analyses are reviewed. These discussions are of critical importance as decisions made during the product design phase typically determine up to 85% of the final costs of products. Additional deliberations are presented regarding activity-based costing (ABC) to define indirect costs related to products/ services and Economic Value added (EVA) to determine the real profitability of an enterprise above and beyond the cost of capital deployed.

Also introduced is capital formation through equity and debt financing along with resource allocation concepts based on adjusted present value (APV) for assets in place and option pricing for capital investment opportunities. By appreciating the project evaluation criteria and the tools of financial analyses, engineers and engineering managers will be in a better position to win project approvals. A critical step to developing technological projects is the acquisition and incorporation of customer feedback. For them to lead, a major challenge is indeed the initiation, development and implementation of major technological projects, which contribute to the long-term profitability of the company.

The important roles and responsibilities of marketing in any profit-seeking enterprise are then clarified along with the supporting contributions expected of engineering managers. Many progressive enterprises are increasingly concentrating on customer relationship management to grow their business. Such a customer orientation is expected to continue to serve as a key driving force for product design, project management, plant operation, manufacturing, customer service and many other engineering-centered activities.

Section III addresses five major topics that are namely engineers as managers/leaders, ethics in engineering/business management, web-based enablers for engineering and management, globalization, and engineering management in the new millennium. These discussions provide additional building blocks to enhance the preparation for engineers and engineering managers to assume technology leadership positions and to meet the challenges in the new millennium.

Engineers are known to possess a strong set of skills, which enable them to do extraordinarily well in certain types of managerial work. However, some of them may also exhibit weaknesses that prevent them from becoming effective leaders in engineering organizations or even from being able to survive as engineers in the industry. The expected norms of effective leaders are described. Steps enabling engineering managers to enhance their leadership qualities and attune themselves to the value-centered business acumen are discussed. Certain outlined steps should be of great value to those engineering managers who want to become better prepared to create new products/ services based on technology, integrate technology into organizations, and lead technology-based organizations.

Many "tried and true" rules are included which serve as suitable guidelines for engineering managers to becoming excellent leaders. Above all, engineering managers are expected to lead with a vision of how to apply company core competencies to create value, insights into how to capture opportunities offered by emerging technologies, and innovations in making products/services better, faster and cheaper, so that they constantly improve customer satisfaction. The concepts of value addition, customer focus, time to market, mass customization, supply chains, enterprise resources integration, and others are also discussed.

Although engineers are known to be ranked quite high in trustworthiness and integrity (ahead of businessmen, bankers, certified public accountants, physicians, lawyers and others), it is important for all engineers and engineering managers to remain vigilant in observing a code of ethics, upholding a high standard of honesty and integrity and become sensitive with other topics related to ethics.

The changes wrought by the Internet are transforming most aspects of company business, including information dissemination, product distribution and customer service. As processor design, software development and transmission hardware technologies continue to advance, their roles in business will surely grow and affect many functions of engineering management in the future. Progressive engineering managers need to know what web-based enablers of engineering and management are currently available and which ones can be applied effectively to promote product customization, expedite new products to market, align supply chains, optimize inventory, foster team creativity and innovation, and improve customer service. Presented in considerate length is a comprehensive set of web-based tools related to product design, manufacturing, project management, procurement, plant operations, knowledge management and supply chain management.

Globalization expands the perspectives of engineers and engineering managers further with respect to divergence in culture, business practices and value. Globalization is a major business trend that will affect many enterprises in the next decades. Engineers and engineering managers must become sensitized to the issues involved and prepare themselves (using the 4-T strategy) to contribute to those enterprises wishing to capture new business opportunities offered in the global emerging markets. They need to be aware of the potential effects of job migration due to globalization and take steps to prepare themselves to meet such challenges. A useful contribution for engineers and engineering managers to make is to create global technical alliances for taking advantage of new technological and business opportunities.

Engineering management will face external challenges in the new millennium. What these specific challenges are, how engineering managers need to prepare to meet these challenges, and how to optimally make use of location-specific opportunities to create competitive advantages will be examined. Progressive companies will also change organizational structures, set up supply chains, expedite e-transformation, and apply advanced tools to serve customers better, cheaper and faster. Globalization is also expected to constantly evolve as the United Nations has predicted that by the year 2020 three of the five biggest national economies will be located in Asia. There will certainly be winners and losers as businesses become more and more global. It is important for future engineering managers to explore prudent corporate strategies for engineering enterprises in the pursuit of globalization while minimizing any detrimental impact on the environment, respecting human rights, and maintaining acceptable work conditions.

How should engineering managers prepare themselves to add value in the new millennium? What are the success factors for engineering managers in the new century? What might be the social responsibilities of engineering managers in the decades ahead? These questions are addressed in the final chapter of the book. Globalization will create ample opportunities for those who know how to properly prepare and equip themselves with the required global mind-set, knowledge, and savvy.

To foster the leadership roles of engineering managers, a six-dimensional model is proposed to emphasize the inside, outside, present, future, local and global dimensions. The management challenges for engineers in these dimensions are discussed.

During two regular academic semesters, the book could be supplemented by in-class discussions of a number of business cases, which focus on engineering and technology management. Examples and answers are incorporated throughout the book. Questions are also included at the end of each chapter to promote in-class exchange among students. Besides a final exam, which could be a take-home comprehensive analysis of a specific business/engineering case, students may also be required to prepare term papers on engineering management topics of their preference in order for them to keep abreast with new developments in the marketplace.

In preparation for this book, the author surveyed engineering management texts published in the last 5–10 years. None of the textbooks surveyed cover "Web-based Enablers for Engineering and Management" (Chapter 12) and "Engineering Management in the New Millennium (Chapter 14). Only a small number of texts addressed some of the issues raised in "Engineers as Managers/Leaders, (Chapter 10) and "Globalization" (Chapter 13). Further, most of these engineering management texts do not cover "Marketing Management for Engineering Managers (Chapter 9). The author believes that engineering managers will be able to play key leadership roles in their organizations if they optimally apply their combined strengths in engineering and management.

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To the School of Engineering and the Department of Industrial and Systems Engineering at the State University of New York at Buffalo, I am indeed indebted for the excellent opportunities offered to me to teach two graduate courses on engineering management since 1987. Initially, I was asked by Dr. George Lee, then dean of the Engineering School and now SUNY distinguished professor, to design and teach new courses on engineering management. The courses notes became the basis for the first edition of the book *Engineering Management: Challenges in the New Millennium*, which was published by Prentice Hall in 2005. This first edition was translated into Korean. It received the Best Book Award 2007 from the International Association for Management of Technology.

As I continue my teaching of the graduate courses on engineering management at the University at Buffalo, I am grateful to the department for the supports offered to me while writing the second edition during the years 2015–2016.

Many of my graduate students in my engineering management courses participated actively in our class projects related to the use of DeepThink methodologies. Their valuable comments and suggestions are sincerely appreciated.

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1

Introduction to Management Challenges for Engineers

1.1 Introduction

In our modern-day economy, customers' needs are changing rapidly, the marketplace is becoming global, and technology is advancing at an ever-increasing speed. To maintain competitiveness in such a challenging environment, companies need effective leaders who understand both technology and business. Engineers with proper management training have great opportunities to make valuable and lasting contributions (Chang 2005; Merino and Farr 2010).

In industry, managers are select employees entrusted with the responsibilities of putting communications means to use, making critical decisions, taking decisive actions, applying resources, and guiding the behavior of internal teams and external business partners to achieve company objectives (Shah 2012; Gomez 2014).

The communications means applied by managers may be verbal or written, with or without body language. The decisions made take into account technical feasibility, resources conservation, and economic viability. The actions taken include planning, organizing, leading, and controlling. The resources utilized involve people, time, capital, equipment, facilities, technology, know-how, and business relationships. The teams guided by managers are individual employees (teams of one), projects, task forces, quality circles, and others. The external business partners may include customers, suppliers, networked partners, and joint ventures or otherwise aligned companies. For individual science, technology, engineering, and math (STEM) professionals to succeed in such an environment, they need to heed the advice of Henry Ford, who said, "The only real security that a man can have in this world is a reserve of knowledge, experience and ability."

This chapter starts with a brief review of the major sectors of a national economy. Then, it discusses the work of engineering managers and practicing engineers, and delineates the differences between these two types of work. Finally, the chapter addresses the challenges faced by engineering managers in the global environment.

1.2 Definitions

It is proper to begin with the language of management. The following are a sample of management terms that will be used frequently throughout this book (Weske 2012).

1.2.1 Management Responsibilities

The management group of a company has the overall responsibility of achieving the company's objectives and meeting the diverse expectations of its stakeholders. The management group is composed of managers at various levels, from chief executive officer (CEO) down to first-line managers (e.g., supervisor, group leader, section head, and manager).

The stakeholders are groups of people who have a stake in the company's performance. These include shareholders, customers, suppliers, employees, and the community in which the company operates. Typical expectations of these stakeholders include:

1. *Shareholders*: Return on investment, dividends, earnings per share, and appreciation in stock price over time
2. *Customers*: Quality of products, acceptable services, flexibility of company to accommodate changing customer needs, efficient delivery, and competitive prices
3. *Suppliers*: Financial stability, market share position, quality production, collaboration efficiency, and on-time payment
4. *Employees*: Innovative company policy and culture, good working conditions, stable employment, and competitive salary and benefits
5. *Community*: Environmentally clean, tax contribution, socially responsible, ethically acceptable practices, and good corporate citizenship

Over time, company management is responsible for satisfying this diverse set of expectation of all stakeholders.

1.2.2 Type of Work

Work is the task performed to add value to the company. Performing the work involves the use of resources (e.g., time, money, energy, tools, human efforts, technologies, and facilities) and applicable procedures. There are three types of work:

1. *Management work*: Plan, organize, lead, and control the efforts of self and others; this requires thinking.
2. *Technical work*: Specialized, nonmanagement work done by engineering managers if others cannot do it for them; this requires doing.
3. *Operating work*: Management and technical work that has been delegated to others; this requires monitoring and controlling.

1.2.3 Chain of Command

The chain of command refers to the chain of direct authority relationships between superiors and subordinates. This is derived from the traditional military systems.

1.2.4 Principle of Unity of Command

According to this principle, an individual worker reports to a single superior.

1.2.5 Efficiency

Efficiency refers to the accomplishment of a given task with the least amount of effort. Being efficient means not wasting resources (e.g., time, money, equipment, facilities, skills, talents, and management attention).

1.2.6 Effectiveness

Effectiveness refers to the accomplishment of tasks with efforts that are commensurate with the value created by these tasks.

The paradigm "All things worth doing are worth doing well" should be replaced by "All things worth doing are worth doing well only to the extent of their contributed value to the company." Engineers and managers need to be value conscious. Perfectionists have no place in a progressive industrial environment.

1.2.7 Strategic and Operational (Tactical) Decisions

Strategic decisions are those that set the direction for the unit, department, and company. These decisions determine what are the right things to do. Examples include which new markets to pursue, what new products to develop, who should be engaged as supply chain partners, and when the right time is to acquire which new technologies to enhance competitive advantages. Operational decisions are those that specify ways to implement a specific task, project, or program. They define how things are to be done correctly.

STEM professionals with managerial responsibilities are involved in making strategic decisions. Others working as technical contributors are typically involved with decisions that are operational in nature.

1.3 Employment Trend in Industries

Graduates of STEM disciplines are typically employed in for-profit industrial companies, which design, produce, market, and service products or services or both to their business clients or individual consumers in the marketplace. In this section, discussions are offered regarding the differences between products and services, the major trend regarding employment into the future, and the special skills needed for STEM graduates to be successful in the years ahead.

1.3.1 Products versus Services

Products differ from services in a number of ways. According to Tidd and Bessant (2013), there are six characteristics that could be used to differentiate them:

1. *Tangibility*: Products are more tangible than services.
2. *Perceptions*: Product quality is assessed based on criteria such as functionality, reliability, durability, and maintainability. Service quality is, on the other hand, perceived based on physical evidence (the physical setting where the service is offered), responsiveness (speed of service and willingness of staff to help), competence (ability to perform the service dependably), assurance (knowledge and courtesy of staff and ability to convey trust and confidence), and empathy (provision of caring and individual attention).
3. *Simultaneity*: Products are typically made in advance of consumption, whereas services are consumed mostly at the time of production. Simultaneity brings about the potential for quality management problems related to the identification and

correction of service errors as well as capacity-planning problems to match supply with demand.

4. *Storage*: Capacity-management problems may arise due to an imbalance between supply and demand. Such problems may be mitigated by pricing (e.g., discounts at off-peak time to induce demand), adding temporary workers or outsourcing or both.
5. *Customer contact:* Services demand a high level of customer contact, some more (medical, business consulting) and some less (financial service, information), whereas products are typically sold in the absence of much customer interaction.
6. *Location*: The proximity factor is more important for services than for products, making services more local and less competitive. Only about 10% of services in the developed economies are traded internationally.

Osterwalder and Pineur (2014) added a few more comparisons between the key features of products and services. Intellectual property rights are very important to products, but not so to services. Products are important as complementarities to other offerings of the same companies, whereas services are not so. For producing products, there is a fixed cost structure, which allows realizable gross margin to increase with production scale, whereas services are predominantly produced on a variable cost structure, which can hardly scale to raise gross margin. In general, products can be used in a variety of contexts because of the inherent generic design knowledge. Services, on the other hand, may require extensive customization to clients' specific needs. It is important for companies to maintain good long-term relationships with clients for products, who are generally knowledgeable. Service clients are typically not technically sophisticated and they are to be served with good project-driven relationships.

It is useful for STEM professionals to recognize the differences between products and services, as the skills needed to successfully work for these employers are different. In the next section, the different growth rates for the products sector versus the service sector will be discussed.

1.3.2 Major Sectors in Industry

The economies of many countries consist of three major sectors: agriculture, manufacturing, and services. In general, the agriculture and manufacturing sectors generate products for sales, whereas the service sector offers services to business clients or individual consumers or both. Over the years, significant changes have occurred in each of these sectors due to technological advancement, market expansion, rapid change in customer needs, and globalization. In countries, such as the United States, the service-providing industry could make up as high as 80% of the total employment in the year of 2014, whereas the roles of the agriculture and manufacturing sectors are steadily declining over time. Figure 1.1 illustrates this remarkable trend.

Other countries are expected to experience a similar path of service expansion in the years ahead, due to the continuous improvement in standards of living, the expansion of the middle-class populations, as well as a change in demographics. As the percentage of elderly people in all countries increases, it will result in demands for services related to health care, hospitality, leisure, financial consultation, investment, and others. Table 1.1 indicates that from 2011 to 2050, the percentage of elderly people in all continents will

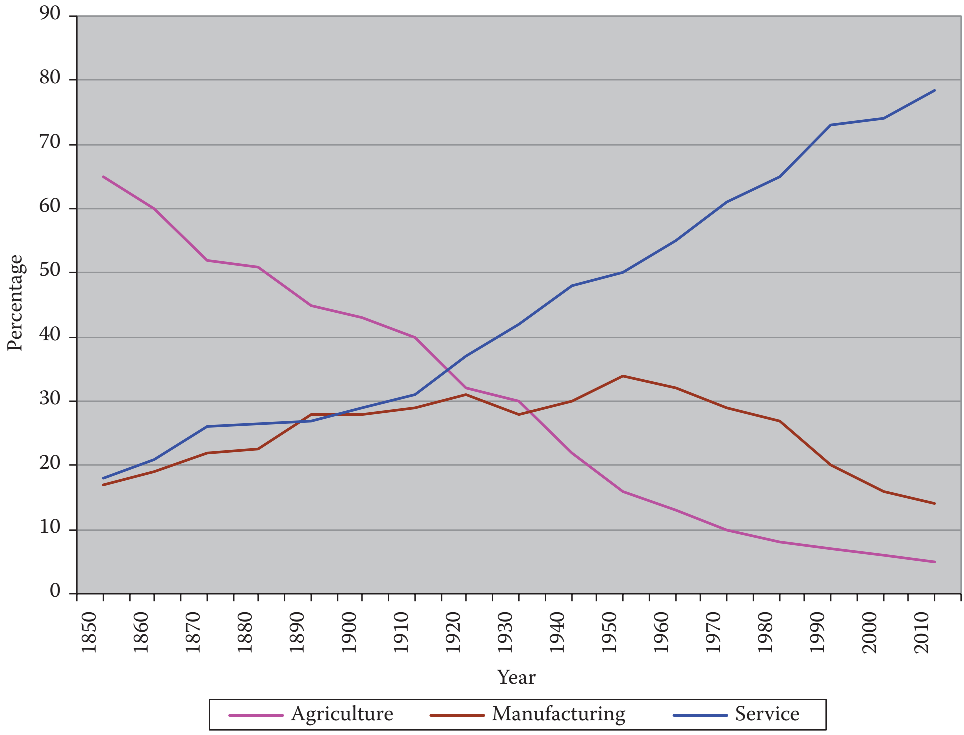

FIGURE 1.1
U.S. employment trend (1850–2010).

TABLE 1.1
Global Demographics

	Percentage of Population Aged 65 or Older		Working Age Persons Per Aged 65 or Older Person	
Continents	**2011**	**2050**	**2011**	**2050**
Europe	19.80	33.16	3.03	1.44
North America	16.61	27.42	3.48	1.81
Asia	7.92	21.49	7.33	2.61
Latin America	8.41	23.33	6.61	2.34
Africa	2.99	7.53	11.43	7.05
World	9.14	19.70	6.14	2.75

Source: Lacey and Wright 2009.

drastically increase and the ratio of working-age persons to older people is expected to decrease accordingly.

The service-providing industry is typically divided into a large number of sectors, as follows:

1. Professional and business services
2. Health care and social assistance

3. State and local governments
4. Leisure and hospitality
5. Educational services
6. Retail trades
7. Financial services
8. Transportation and warehousing
9. Information
10. Utilities

In Figure 1.2, the projected percentage changes in U.S. employment by sector (2010–2020) are forecast. Table 1.2 lists the projected job growth in the United States.

Companies providing services need talented people who are in a position to innovate new ways to make present-day services cheaper, faster, better, and more convenient for users. Opportunities are also available due to generally perceived needs to invigorate productivity in the service sectors, which typically lag behind that of the manufacturing sector. Tools such as Lean Six Sigma, total quality management, automation, value stream mapping, and other are now increasingly applied to the service industry. More recently, advanced tools, such as big data, analytics, service-oriented architecture (SOA), cloud computing, and web services are being readily applied to discover insights from internal as well as external customer databases to create competitive advantages in the marketplace.

As the need for highly skilled professionals in the service sectors becomes evident, it is advisable for STEM professionals to prepare themselves well to capitalize on such new opportunities offered in the future, and not to limit themselves to only pursuing product-related job opportunities.

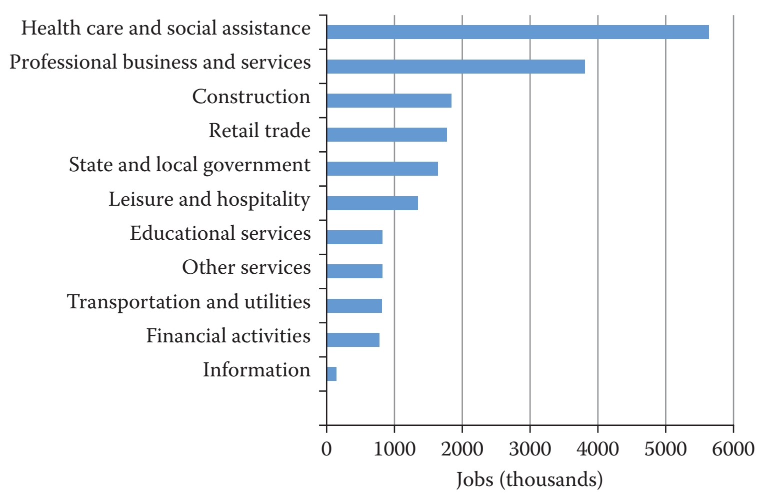

FIGURE 1.2
Projected percentage change in US employment (2010–2020).

TABLE 1.2

Projected Job Growth in the United States (2010–2020)

	Year 2010	Year 2020	Change	Percentage
Service-providing sectors	112,730.10	130,680.10	17,950.00	100
Health care and social assistance	16,414.50	22,053.90	5,639.40	31.42
Professional and business services	16,688.00	20,497.00	3,809.00	21.22
Retail trade	14,413.70	16,182.20	1,768.50	9.85
State and local government	19,513.10	21,154.80	1,641.70	9.15
Leisure and hospitality	13,019.60	14,362.30	1,342.70	7.48
Transportation and warehousing	4,183.30	5,036.20	852.9	4.75
Other services	6,031.30	6,850.70	819.4	4.56
Educational services	3,149.60	3,968.80	819.2	4.56
Financial activities	7,630.20	8,410.60	780.4	4.35
Wholesale trade	5,456.00	6,200.00	744.1	4.15
Information	2,710.90	2,851.20	140.3	0.78
Federal government	2,968.00	2,596.00	−372	−2.07
Utilities	551.8	516.1	−35.7	−0.20
Total U.S. job growth, all sectors	143,068.20	163,537.10	20,468.90	—
Fraction of service jobs in total	—	—	87.70%	—

Source: U.S. Department of Labor, 2012, *Occupational Outlook Handbook*, Skyhorse Publishing (April 1).

1.4 STEM Professionals as Effective Technical Contributors

1.4.1 Types of Work Done by Technical Contributors

Practicing engineers (technical contributors) are empowered to do things correctly (mostly operational) and to upgrade the ways that things are done. When assigned to perform specific work, a practicing engineer is typically told of the specific work objectives as well as any time line, budgetary, technological, and other constraints that may apply. The engineer is then expected to develop a project plan, jointly define standards with his or her superior, select methods of performing the work, carry out the tasks, and deliver results. A document is prepared to summarize the project; this includes conclusions; the impact of the outcome on the objectives of the group, unit, or company; and possibly suggestions related to potential improvements in methodology and future technical applications of the results.

The performance of practicing engineers is evaluated according to how well they carry out their technical assignments within the time and budgetary constraints, as well as the value of the project outcome to the company. Young engineers entering an organization are typically assigned tasks of a highly technical content for which their academic training is best utilized.

To perform well as technical contributors, engineers are advised to pay attention to the following five steps:

1. *Demonstrate technical competence and innovative capabilities*: In their early years, engineers need to demonstrate excellent technical skills in performing tasks and projects. They practice fundamental engineering principles correctly, deliver work that

is technically free of errors, and are sensitive to time and budget constraints. It is also critically important for engineers to demonstrate their innovative capabilities in product design, problem solving, conflict resolution, and other technological areas.

2. *Practice people skills:* Engineers should ensure that they communicate effectively with others in both verbal and written forms. They need to interact with peers and management in an acceptable manner. Their interactions with management will be strongly enhanced if the engineers become familiar, through self-study or academic courses, with the mind-sets and perspectives of the company managers and with managerial issues and problems. They also need to demonstrate that they are easy to work with and get along well with most people. Ravi Zacharias said, "There is never a good reason to be unkind."
3. *Show an unfailing reliability:* Engineers need to show that they are reliable in taking on assignments that add value to their management and are capable of discharging responsibilities delegated to them.
4. *Be proactive:* Engineers should proactively seek team assignments, project coordination, and other roles to practice their managerial skills, foster teamwork, and showcase leadership qualities. If opportunities do not knock, build a door.
5. *Work skills*: STEM professionals should equip themselves well with various work skills that are expected in industry. These include (1) communications, (2) interpersonal skills, (3) negotiation, (4) conflict resolution, (5) problem solving—root cause analysis, (6) self-motivation, (7) project management, (7) team building, (8) leadership and vision, (9) creativity and innovation, (10) entrepreneurship, (11) stress management, (12) decision-making, (13) critical thinking, (14) time management, (15) study habits—learning to learn, (16) networking, (17) value-based choice-making, (18) literature search and data analysis, (19) work ethics and integrity, (20) use of social media, (21) relationship management, (22) budget and economics, (23) engineering fundamentals, (24) application of system thinking, (25) use of advance technological tools (Skype, NetMeeting, video conference, mobile devices, etc.), and (26) keep knowledge and ability current.
6. *Exhibit a readiness for advancement*: Engineers need to ready themselves for assuming a higher level of technical responsibility so that their employers are able to entrust more challenging responsibilities to them. Engineers should strive to constantly enrich themselves by acquiring new knowledge and creating increasingly more value for their employers.

1.4.2 Interaction and Collaboration with Others

A typical modern-day engineering organization may have many departments, each focusing on a group of specific functions. These groups may include (1) production and manufacturing, (2) construction, (3) design engineering, (3) systems engineering, (4) systems and equipment maintenance, (5) project engineering, (6) program management, (7) process development, (8) product development, (9) technology development, (10) customer service, (11) applied research and development (R&D), and (12) others. Engineers may work in any of these departments. Some engineers may elect to stay in specific functional areas for a long period. Others may prefer to move from one functional area to another to attain a well-rounded base of experience.

Figure 1.3 displays the typical interactions between various engineering and nonengineering groups. Engineers are focused on creating value for their employers through their

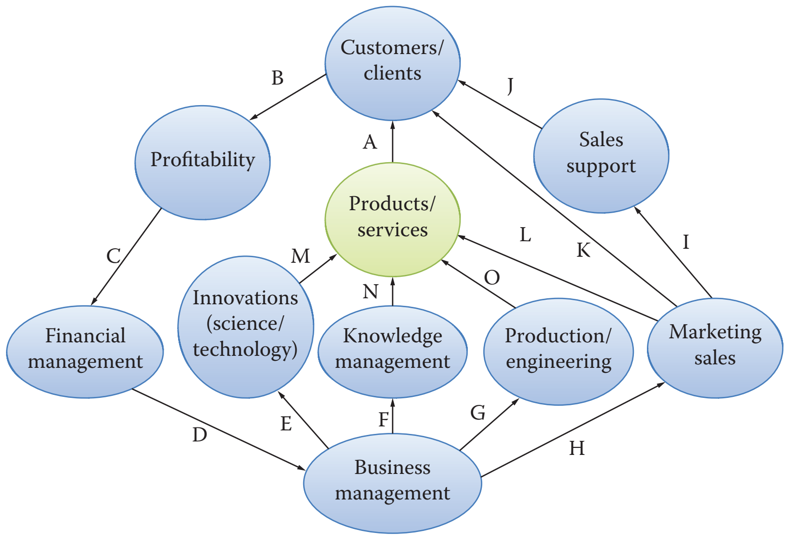

FIGURE 1.3
Interactive functions within a product/service enterprise. Note that the linkages A to O are symbolic representations of the active transactions between the respective business units.

technical work, although they may get involved with various nonengineering functions from time to time.

Different types of professional work require skills at different quality levels. Table 1.3 illustrates the 10 commonly defined quality levels. New and innovative services are typically realized by people at service quality level 10.

Companies in industry need to pursue strategic differentiation and operational excellence in the products/services that they offer in order to sustain and extend market competitiveness and achieve long-term profitability (Chang 2014). In so far as strategic differentiation is concerned, market competitiveness must be built on product/service innovations such that these value packages offered to customers are constantly renewed

TABLE 1.3
Skill Quality Level

Level	Description
1	Able to follow role script in method when all resources are made available and there are no exceptions and supervisory function is active to validate each step before execution to avoid errors
2	Able to follow role script in method when all resources are made available and there are no exceptions to be processed, with minimal supervision and corrections from project manager and other levels/roles using method
3/4/5	Able to follow roles script in method when all resources are made available and there are few/several/many exceptions (nonstandard requirements)
6	Able to follow role script in method when not all resources are made available and there are many exceptions (nonstandard requirements)
7	Able to follow role script in method and improvise as required
8	Able to do all roles in method
9	Able to do all roles in all methods
10	Able to improvise and innovate new offerings

and uniquely differentiable from the competition. Marketing management, financial analysis, and cost accounting are important tools to employ, when choices need to be made to achieve long-term strategic advantages. These topics are covered in the second part of this book. Operational excellence is also important, as companies need to minimize wastes, streamline operations, and enhance productivity to maximize profitability. Engineering management principles related to planning, organizing, leading, and controlling will be needed to guide these operations. These subjects are covered in the first part of this book.

To be successful in such an environment, professionals need to exhibit capabilities related to communications, teamwork, collaborations, and results-orientation (Chang 2010). It is also important for them to possess:

1. *Customer-focused mind-set:* A service mind-set consists of practicing a customer-focus paradigm in the creation, delivery, and servicing of value packages to meet customers' important needs with a keen understanding that achieving customer satisfaction is the driving force for long-term corporate profitability. Apply marketing tools to understand customers' needs, foster customer collaboration, and create customer expectations.
2. *Vision and leadership:* Create vision, set direction, and make decisions that determine values in relation to new product/service offerings, business models, supply chain partnerships, market segments, and emerging technologies.
3. *Creativity and innovation:* Invent new product/service offerings, and pursue innovative programs to achieve market success.
4. *Productivity and value creation:* Utilize management tools to monitor business activities, create value through customer interactions, and improve all operational processes.
5. *Design and development:* Engage emerging technologies (e.g., big data, analytics, SOA, and Internet-based enablers), to invent new products/services and improve existing ones.
6. *Ethics and professionalism:* Set high standards and implement corporate codes of ethics.
7. *Global orientation:* Ensure methods of supply through tiered partnerships, and exploit global networks of resources to capitalize new opportunities.

1.4.3 Value-Adding Opportunities

As a technical contributor, every STEM professional would report to a superior who is typically a supervisor or manager. The superior makes decisions that will have a profound impact on the engineer's contributions to the company and hence on his or her professional career. Exposure to the functions, concepts, skills, and best practices of engineering management allows the engineer to better align his or her own work with the needs of his or her superior and hence that of the company. The engineer is then in a better position to accept the fact that his or her superior will typically decide whether or not to adopt a new technology, program, or project primarily based on the value it can add to the company. The decision is likely to take into account the resources (e.g., money, people, time, technologies, and business relationships) required for implementation. The decision will not likely be made based on inherent technological sophistication, innovative strength, rational elegance, or theoretical robustness.

TABLE 1.4

Work Done by Technical Contributors and Managers

Characteristics	Professionals	Managers
Focus	Technical/scientific tasks	People (talents, innovation, relationships); resources (capital, knowledge, process know-how); projects (tasks, procedure, policy)
Decision-making basis	Adequate technical information with great certainty	Fuzzy information under uncertainty (people's behavior, customer needs, market forecasts)
Involvement	Perform individual assignments	Direct work of others (planning, leading, organizing, controlling)
Work output	Quantitative, measurable	Qualitative, less measurable, except financial results when applicable
Effectiveness	Rely on technical expertise and personal dedication	Rely on interpersonal skills to get work done through people (motivation, delegation)
Dependency	Autonomous	Interdependent with others
Responsibility	Pursue one job at a time	Pursue multiple objectives concurrently
Creativity	Technology centered	People centered (conflict resolution, problem solving, political alliance, networks building)
Bottom line	"How" (operational)	"What" and "why" (strategic)
Concern	Will it work technically?	Will it add value (market share, financial, core technology, customer satisfaction)?

Source: Adapted and revised from: Aucoin, B. Michael. *From Engineer to Manager: Mastering the Transition*, Artech House, Norwood, MA, 2002.

Value is said to have been added if the company's profitability is derived from

Increased sales revenues: For example, due to new product features, better customer service, novel logistics in the delivery of products/services, shorter time to market, and so on, when the company devotes a considerable amount of effort to the creation of strategic differentiation.

Reduced cost to do business: For example, due to improved engineering and manufacturing productivity, raised operational efficiency, new synergy among aligned business partners, simplified product design, better quality control, and so on, as pursued by progressive companies in achieving operational excellence.

The superior sets project priorities. Priorities are usually set based on whether the anticipated value of a project is large or small, short term or long term, direct or indirect, and certain or uncertain. Exposure to *Engineering Management: Meeting the Global Challenges* makes engineers more effective in increasing their cumulative value contributions to their employers.

Table 1.4 summarizes the contrasting difference between work done by technical contributors and engineering managers.

1.5 Management and Leadership

Engineers interested in moving into leadership positions need to know what it takes to be selected as managers by their employers. In order to lead their enterprises to greater prosperity, they need to prepare themselves to accept leadership roles and responsibilities by honing their people skills and interacting effectively with peer managers in other corporate functions, and become versed in the use of Internet-based management and technology tools. They also must nurture a clear vision for the companies they work for, be innovative and creative in product development and other ways of utilizing emerging technologies, and possess the required business savvy with a customer focus and a global orientation. This book assists engineers in acquiring the skills and attributes deemed essential for assuming leadership roles in the new millennium.

Not all engineers are interested in becoming managers. This book, *Engineering Management: Meeting the Global Challenges*, is useful to both engineers who want to remain technical contributors and those who elect to become managers.

STEM professionals who aspire to become managers are advised to fully understand these differences and the requirement associated with management work. An individual should assess the compatibility of these implied requirements with his or her personality, aptitude, value system, personal goals, preparation, and other factors so that he or she is convinced that taking on managerial responsibilities will indeed lead to long-term happiness.

1.5.1 Readying Engineers to Accept Managerial Responsibilities

For those engineers who aspire to become managers, a comprehensive exposure to the topics reviewed in this book enhances their readiness for being selected when such managerial opportunities arise. Knowledge is power. The new knowledge gained from this book can motivate engineers to experiment and to excel. They accumulate experience as they systematically correct their own deficiencies and practice interpersonal skills, decision-making, problem solving, delegating, cost accounting, strategic planning, project management, and team coordination. Both the new knowledge gained and the experiences accumulated provide them with a decisive advantage over other management candidates.

Engineering managers must be able to lead. This is particularly true in the dynamic marketplace of the new millennium, which is affected by sophisticated communications tools, operational excellence enablers, flexible supply chains, and business operations of global proportions. Operational excellence enablers are tools that are Internet based (see examples discussed in Chapter 12). These tools enhance the efficiency of product design, project management, plant operations, facility maintenance, innovations, knowledge management, marketing and sales, enterprise resources planning and integration, and procurements. Since programs and projects will become increasingly interdisciplinary and complex in the future, decision-making is likely to involve the use of web-based tools and the participation of team members who have divergent cultural backgrounds, value systems, business priorities, and work experience. Also much needed is the push for technological innovations, which many engineers are particularly qualified to provide. Those engineering managers who are innovative and have both technological insights and business savvy will have opportunities to create significant value for and be richly rewarded by their employers in the new millennium (Cooper 2011).

This book is written to prepare STEM professionals to become better technical contributors or engineering managers to become better leaders in technical organizations, so that all of them will add substantial value to their employers in the new millennium. This book shows that certain management principles do not change over time (Griffin 2012). However, management practices do change in response to changes in customers' needs, employees' attitudes, business models, technologies, organizational structures, resources, and external business relations. Managers must be able to lead and manage these changes.

A good strategy for young STEM graduates is to learn the fundamentals of management (principles, skills, functions, roles and responsibilities, success factors, etc.), and then seek opportunities to actively practice these skills, functions, principles, and management roles. Opportunities to do so may exist in professional societies and volunteer organizations (e.g., the United Way, churches, boy scouts, and girl scouts). As more management experience is accumulated, proficiency will result and allow the engineer to naturally stand out when management openings become available in the future.

Example 1.1

Several U.S. universities offer the academic degree program that is concentrated on engineering management. Others have developed the degree program for management of technology. Are they fundamentally different from one another?

Answer 1.1

These two types of degree programs are essentially similar, with minor differences in the course work involved. Both programs are aimed at training managers to become managerial leaders in technology.

The management of technology degree program was envisaged to correct a deficiency noted in the U.S. educational system (National Research Council 1987). This degree program is designed to address important management issues, such as those enumerated here, which were neglected in the master of business administration program that existed at the time:

1. Integrating technology into the overall strategic objectives of the firm
2. Getting into and out of technologies more efficiently
3. Assessing and evaluating technology more effectively
4. Developing better methods for transferring and assimilating new technology
5. Reducing new product development time
6. Managing large, complex, and interdisciplinary or interorganizational projects, programs, and systems
7. Leveraging the effectiveness of technical professionals

Currently, the degree programs in engineering management offered by many U.S. universities address these topics as well.

1.5.2 Characteristics of an Effective Engineering Manager

Engineering managers have engineering training and specific technical knowledge and experience, and are accountable for the results of the unit, section, or department they head up. Generally speaking, an engineering manager needs to be motivated to acquire knowledge (e.g., roles, functions, and vocabulary) and skills; prepare mentally (job outlook, management orientation, personality traits, and flexibility); and be determined to diligently practice the principles of engineering management. Many skills of engineering management are learnable.

The effective engineering manager is someone who has a clear vision to lead his or her unit, is a rational and organized individual, devotes attention to focus on what customers are looking for (e.g., quality, convenience, flexibility, speed of service, and friendliness in interactions), and practices a high standard with respect to ethics, fairness, and honor. As a rule, managers decide what should be done (strategic), and technical contributors determine how things are to be done (tactical). As an engineering manager rises in an organization, his or her daily decisions will become more strategic. The CEO of a company makes strategic decisions only.

1.5.3 Resources Controlled by an Engineering Manager

In general, the engineering manager has a number of resources at his or her disposal, which are to be optimally applied: (1) managerial time for planning, directing, monitoring, and controlling; (2) staff with proper expertise available; (3) budget authorized to use; (4) access to corporate hardware and know-how; (5) access to external capabilities (e.g., business partners, independent inventors, and university experts); and (6) access to company-internal management information. These resources are effectively utilized to (1) define the priority of all tasks to be done; (2) determine the specific objectives of each task to be accomplished; (3) specify the constraints for each task (such as time, budget, outcome); (4) invite the assignee to suggest specific ways to accomplish the task; (5) monitor progress; (6) document the task results; (7) glean important learning from this case; and (7) offer individual feedback and evaluation.

1.5.4 Nature of Work by Engineering Managers

The work of engineering managers is four dimensional. Engineering managers need to interface with and manage the interactions with subordinates, as well as coordinate their own management actions with those of other managers and peer groups. They manage their own time and efforts. They also attempt to anticipate the requirements of their superiors by making recommendations for future courses of action. Figure 1.4 illustrates this four-dimensional nature of work.

Engineering managers plan, organize, lead, and control people, teams, money, technology, facilities, and other resources to achieve the business objectives of the company. To ensure company operations for the short term, they pay attention to problem solving and conflict resolution. As a rule, engineering managers do not perform the technical work themselves. Instead, they work through people. Their job is to decide what the unit, department, or company should be doing to advance the objectives of the company and then assign resources to implement their decisions.

An illustration of managerial concern is an issue related to product development. Some companies initiate new product development on a market-driven basis. First, they use market surveys and customer feedback to define product concepts of potential interest to customers. Then they secure resources to develop the product concepts, manufacture the

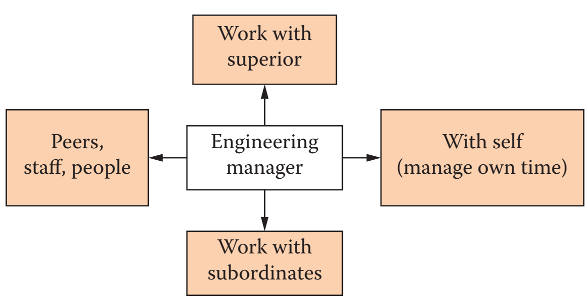

FIGURE 1.4
Four-dimensional work of engineering managers.

prototypes, conduct tests of a prototype to further improve design details, and offer customer services to market the products involved. Doing so allows them a high probability of achieving commercial success. Other companies adopt a technology-driven approach. They first invent and develop new technology, and then they incorporate the resulting inventions and innovations in products that they hope to sell to the marketplace. Each of these approaches has advantages and disadvantages. Surveys show that both approaches have yielded successes and failures.

Another example is the potential difference in opinion between departments when deciding on "buy versus build" options and on setting task priorities. Still another area of potential disagreement is the choice about the level of standardization in product design that reduces cost while allowing a sufficient level of innovation to enhance competitiveness. In general, enforcing a high level of standardization with strict rules and guidelines tends to impede creativity and innovation, as illustrated by Figure 1.5. Managers are expected to constantly interact and work closely with other managers to resolve such differences.

For those engineers who elect to become managers, there are skills that can be readily learned to make them more efficient and effective. These include time management, work habits, people-related skills (such as team building, communications, and motivation), and use of decision support tools (e.g., multicriteria decision-making [Triantaphyllou 2010], what-if analysis by modeling, risk analysis, Monte Carlo simulation, forecasting, statistics, regression, linear programming, optimization, and office technologies).

Example 1.2

The company wants to develop a new product to preemptively enter the marketplace. Current information from marketing is sketchy, and the market size cannot be predicted accurately. Indications are that foreign imports are about to foray the market, causing the company to lose the precious opportunity of a preemptive entry.

Should the company initiate a product development program now or wait for more marketing information? Are there other options available to the company?

Answer 1.2

Yes, there is a third option: The company can act as a distributor and import the foreign product itself, but with its own brand name. This will allow the company to gauge the market acceptance of a low-quality and low-price product. If the results show that

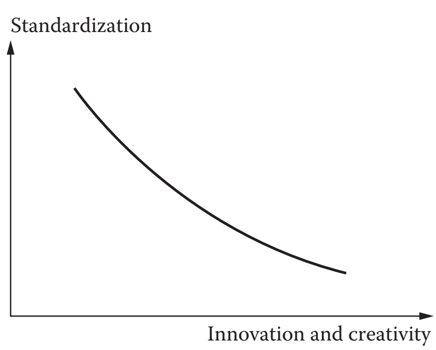

FIGURE 1.5
Standardization.

customers like the product and the market size is large, then the company can continue importing or develop a low-cost alternative to compete.

Selling a foreign product under the company name requires that the company enter into a private-label production contract with the foreign producer. Typically, such an arrangement includes some of the following elements:

- The contract is good for a predetermined period (e.g., two years) and renewable with mutual consent. The company agrees to pay a unit product cost of x dollars for at least y units per year. The foreign producer agrees to hold the product defect rate at or below z per thousand. The foreign producer remains an exclusive subcontractor to the company for the product types in question during the contract period.
- The company respects all proprietary design and other know-how of the foreign producer. The company is obliged not to use any proprietary design of the foreign producer for the development of its own product or for use by its new production partners.
- The company is responsible for marketing, distributing, selling, and serving the product in the target market (e.g., the United States). The foreign producer agrees to upgrade product design, based on the marketing inputs of the company.
- The company strives to invest in the foreign producer for creating the next generation of products. The foreign producer has the first-refusal rights to accept such investment (i.e., funds and technology).
- Each party can cancel the arrangement after an initial period of collaboration. The foreign producer can go to someone else for marketing the product in the target market. The company may develop its own products or engage another foreign producer as a subcontractor. Thus, selling the foreign product does not preclude the company from selling a similar product after the contract has expired. Companies change subcontractors all the time.

Such a private-label production arrangement is typically a win–win arrangement. The company can preemptively explore the market—that is, test the market and get valuable feedback from customers regarding useful product features—without spending a lot of resources. The foreign producer achieves instant profitability that is assured for the contract period, plus the potential of additional future investment from the company for the next-generation product design and production.

1.6 Becoming Effective Managers in the New Millennium

Future STEM professionals interested in assuming leadership roles in industry need to acquire the useful T-personality by having a broad set of skills for managing relationships, communicating and collaborating with others in multiple disciplines, and envisioning the future to define what are the best courses of action to take in moving forward. They also need to possess in-depth skills in specific domains to enable them to actually implement some of the required work.

The basic functions of engineering management provide engineers and engineering managers with foundational skills to manage themselves, staff, teams, projects, technologies, suppliers, and global issues of importance. Engineers innovate to solve problems and minimize conflicts to achieve the company's objectives. They follow the best practices in industry to monitor and control internal operations. They use proper methods to make rational decisions and take lawful and ethical actions (Eisenfuehr 2010).

To facilitate the interaction with peer groups and units, it would be advisable for engineering managers to acquire a broadened background in cost accounting, financial analysis, managerial finance, and marketing management. Thus, the special cases of activity-based costing, ratio analysis, risk analysis by the Monte Carlo method, economic value-added accounting, and marketing strategies are elucidated in Chapters 6 through 8. It is believed that these new building blocks of added knowledge would enable engineers and engineering managers to gain a better appreciation of the business of the company and its stakeholders.

A critical step to developing technological projects is the acquisition and incorporation of customer feedback. By understanding the project evaluation criteria and the tools of financial analysis, engineers and engineering managers will be in a better position to secure project approvals. For them to lead, a major challenge is indeed the initiation, development, and implementation of major technological projects that contribute to the long-term profitability of the company.

The discussions on ethics, engineers as leaders, and Internet-based enablers for fostering operational excellence provide additional building blocks to enhance the preparation of engineers and engineering managers to assume technology leadership positions. Operational excellence encompasses all activities that enhance productivity and improve effectiveness (such as applying enterprise resources planning tools, making procurement more efficient via e-markets, enhancing customer services through Internet portals, improving logistics using global positioning systems, etc.). Many tried-and-true rules are included that serve as good guidelines for engineers and engineering managers to become excellent leaders. Above all, so that they constantly augment the satisfaction of customers, engineering managers are expected to lead by their vision of how to utilize company core competencies to add value; by their insights into how to capture opportunities offered by emerging technologies; and by their innovating ability in making products and services better, faster, and cheaper. The concepts of value addition, customer focus, time-to-market speed, mass customization, supply chains, enterprise resources integration, and others are also reviewed.

Globalization is a major business trend that will affect many enterprises in the next decades (Ritzer 2015). Knowledge of globalization expands the perspectives of engineers and engineering managers with respect to divergences in culture, business practices, and value. Engineers and engineering managers must become sensitive to the issues involved and prepare themselves to contribute to enterprises that wish to capture new business opportunities offered by the high-growth global markets in emerging countries. Engineers and engineering managers need to be aware of the potential effects of job migration due to globalization and take steps to prepare themselves to meet such challenges.

STEM professionals aspiring to leadership roles in the future should strive to practice the engineering management functions (such as planning, organizing, leading, and controlling) as applied to teams, projects, and programs, while making use of their understanding of business fundamentals (cost accounting, financial analysis and management, and marketing management), to exert their leadership roles in creating strategic differentiation and operational excellence for their employers.

Example 1.3

John Snyder, an engineering manager, presented to the board of directors a project based on the results generated by Steve Hill, one of his staff members. The board approved the project and praised John for the excellent work done. At that moment, John failed to mention to the board that the work was actually done by Steve. Afterward, John felt bad about it and recommended to give Steve a bonus.

How would you assess John's handling of this situation?

Answer 1.3

It would have been more correct for John to initially point out to the board that Steve was the one who did the actual work. However, John's way of handling this situation is acceptable in industry, since he did eventually recognize Steve's contribution by offering a bonus. John should follow through by including Steve in his subsequent monthly progress reports to his boss, the vice president of engineering, to set the records straight and by formally recognizing Steve's work in a staff meeting.

1.7 Conclusions

Products and services are typically offered by for-profit enterprises in industry, which in turn engage highly skilled STEM professionals to perform various value-adding tasks. These professionals interact with their in-house counterparts, as well as with stakeholders external to their organizations (such as customers and suppliers) for work related to the design, testing, marketing, and production of their specific products and services. The skills required for STEM professionals to succeed in industry are thus complex and demanding, as illustrated in this chapter.

For STEM professionals to become ready to assume leadership roles in industry, they need to prepare themselves properly, by acquiring a customer-oriented mind-set, displaying the T-personality to contribute to both strategic differentiations (creating novel products/services) and operational excellence (improving process efficiency and enhancing the cost-effectiveness of all operations) of their enterprises.

It is suggested that STEM leadership be built by adding value through the creation of strategic differentiation (in new products and services) and operational excellence (process efficiency and productivity) for employers, while focusing on actively pursuing creativity and innovation in an ethical manner in a globalized environment, and utilizing basic skills in managerial fundamentals (planning, organizing, leading, and controlling) and business fundamentals (accounting, finance, and marketing management). This book contains three sections, which include:

1. Engineering management fundamentals (planning, organizing, leading, and controlling)
2. Business fundamentals (accounting, finance, and marketing management)
3. Leadership in the new millennium (leadership preparation, ethics, globalization, and operational excellence)

These three sections are specifically designed to address these domain skills and knowledge to foster the building of STEM leaders in the globalized environment.

A large number of themes permeate this book. The principal objective of this book is to offer comprehensive discussions on engineering management functions, business fundamentals, and STEM leadership, which are designed to provide a broad foundation for preparing STEM professionals to meet their future challenges in the new millennium.

QUESTIONS

1. Tom Taylor, the sales manager, was told by his superior, Carl Bauer, to take an order from a new customer for a batch of products. Both Tom and Carl knew that the products ordered would only partially meet the customer's requirements. But Carl insisted that the order was too valuable to lose. What should Tom do?
2. Nancy Bush, the plant manager, needs to decide whether to make or buy a component for the company's core product. She would like the advice of her production supervisors, since they must implement her decision. However, she fears that the supervisors will be biased toward making the component in-house, as they tend to favor retaining more work for their people. What should Nancy do?
3. Student A, in order to graduate on February 4, works hard to finish her master of engineering report by the due date of January 8. She is planning to return to her home country immediately thereafter and get married. If she graduates on June 10, the next available graduation date, she will have to pay a tuition fee to keep her student status active for one more semester. That would be a substantial financial burden for her.

   Her advisor, Professor B, is hesitant to accept the report as presented. The report includes a major marketing activity designed by Student A to promote the new service package of a local company. Because of logistics, this major marketing activity is scheduled to take place on January 20. No customer feedback data, which are required to demonstrate the value brought about by the report, are available before January 8. Professor B cannot bend the rules to pass the report without these data.

   Put your innovation hat on and recommend a way to resolve this conflict.
4. The engineering manager of Company A proposes to install an automated bar-code scanner costing $4000. He estimates that he can save about 100 hours of labor time per month, as products can now be scanned much faster. He reasons that at the wage rate of $15 per hour, the benefit for using the automated bar-code scanner is $1500 per month, and the scanner can be paid back in 2.67 months.

   As the president of Company A, do you agree or disagree with the way he computes the cost–benefit ratio? Why or why not?
5. The new millennium imposes a number of challenges on business managers, who are different from engineering managers and technology managers. Name a few such challenges.
6. In the literature, it is generally said that innovations in the service sectors are lagging behind those in the manufacturing sectors. Explain why this might indeed be so.
7. There have been a number of articles in the business literature proclaiming the potentially large contributions that data mining could make to the service sectors. Show an example in which the application of data mining had actually made a difference to a service company.

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Section I

The Functions of Engineering Management

Section I of this book addresses the basic functions of engineering management, such as planning (Chapter 2), organizing (Chapter 3), leading (Chapter 4), and controlling (Chapter 5). These functions provide science, technology, engineering, and math (STEM) professionals and managers with foundation skills to manage themselves, staff, teams, projects, technologies, and global issues of importance.

Best practices are emphasized as pertinent standards for goal setting and performance measurement. STEM professionals and managers solve problems and minimize conflicts to achieve the company's objectives. They use the Rational Decision method, among others, to make decisions and take lawful and ethical action. They apply Monte Carlo methods to assess projects involving risks and uncertainties. They engage emerging technologies, motivate a professional workforce of diverse backgrounds, develop new generations of products and services in a timely manner, and constantly surpass the best practices in industry.

The roles of STEM professionals and managers in strategic planning, employee selection, team building, delegating, decision-making, and managing creativity and innovations are explained. The development of managerial competencies is emphasized.

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2

Planning

2.1 Introduction

Planning, a major function of engineering management, is the work done by an engineering manager to predetermine a course of action. Planning defines who will do what, how, where, when, with which resources, and for what objectives. The purpose of planning is to enhance the effectiveness and efficiency of the company by providing focus and direction (Daft 2015; Institute of Leadership & Management 2007; Zucker 2007; Axson 2010).

Planning is made necessary by rapid changes in technology (such as Internet-based management tools, enterprise resource planning software, big data analytics, broadband communications options, and mobile access), the environment (customers, global resources, competition, and marketplace), and organizations (such as mergers, acquisitions, supply chain networks, alliances, and joint ventures). Louis Pasteur said, "Chance favors the prepared mind."

In this chapter, we will discuss the differences between strategic and operational planning, the planning roles of engineering managers, and the four specific planning activities (i.e., forecasting, action planning, issuing policy, and establishing procedure) that every engineering manager needs to master.

2.2 Types of Planning

Managers at various levels in a company engage in two types of planning: strategic planning and operational planning. Both types of planning add value to the company.

2.2.1 Strategic Planning

Strategic planning sets the goals, purpose, and direction of a company. The top-level engineering managers (i.e., chief executive officer [CEO], chief technology officer, and vice president of engineering) are usually involved in strategic planning for the company (Johnson 2015; Fogg 2010).

Strategic planning focuses on identifying worthwhile future activities. Specifically, strategic planning ensures that the company applies its resources—core competencies, corporate know-how, proprietary technologies, skilled manpower resources, business relationships, and so on—effectively to achieve the short- and long-term goals of the company

(Akdeniz 2015). The company's future is painted on a wide canvas. The plan must have much foresight. It deals with questions such as

1. What are the company's mission, vision, and value system? The mission statement of a company defines why the company exists in the first place, which market segments it serves, and what it will do to serve them. The vision statement spells out the aspirations of the company with respect to its asset size, market position, business standing, ranking in industrial sectors, and other such metrics. The value system is the externalization of five or six specific corporate values emphasized by the company. Some typical values favored by U.S. industrial companies include quality, innovation, social responsibility, stability, honesty, quality of life, and empowerment.
2. What business should the company be in?
3. Does the company need to change its product portfolio, market coverage, production system, or service capabilities? If so, why? Strategies of constant change develop a chameleon culture in which the organization seeks to reinvent itself to become leaner, flatter, more flexible, and more profitable.
4. What specific goals (such as profitability, market share, sales revenue, technology leadership position, global penetration, etc.) should the company accomplish, by when, with what investment, and by which core competencies?
5. What business networks should the company establish via supplier alliances, co-marketing partnerships, production joint ventures, and other forms of collaboration?
6. Which new products should the company offer?
7. What core technologies should the company maintain, develop, acquire, or utilize?
8. Which performance metrics are to be used for monitoring the company's progress?
9. How should the company tackle the daunting challenge of making innovation central to the company's products, processes, or relationships?

Science, technology, engineering, and math (STEM) professionals who participate in such planning activities know that they need to set aside their parochial technology mindset and look at the broader picture. They also know that they need to keep lots of iron in the fire and it is whichever ones are coming to fruition that they go with. The horizon of strategic planning is usually spread over 5–10 years, although it may be reviewed at more frequent intervals to adjust to potential changes in the marketplace.

2.2.2 Operational Planning

Managers at both middle level (managers and directors) and lower level (supervisors and group leaders) perform operational planning to define the specific tactics and action steps needed to accomplish the goals specified by top management (Duggan 2011). Managers and directors break down the company goals into short-term objectives. Supervisors and group leaders specify events and tasks that can be implemented with the least amount of resources within the shortest period of time. Operational planning ensures that the company applies its resources efficiently to achieve its stated goals. Questions considered in operational planning include the following:

1. What is the most efficient way of accomplishing a project with known objectives?
2. What is the best way to link up with three top suppliers in the marketplace for needed parts?
3. What are the operational guidelines for performing specific work?

Operational planning involves a process of analysis by which a corporate goal or a set of corporate intentions is to be accomplished by performing a group of action steps. These steps are then formalized for easy implementation. Furthermore, the consequences for the business are articulated at each step. Operational planning focuses on the preservation and rearrangement of established categories (e.g., major strategies defined by upper management, existing products, and organizational structures). Operational planning is essentially a programming task that is aimed at making the attainment of various strategic goals possible. Operational planning is also called *platform-based planning* because it extrapolates future results from a well-understood, predictable platform of past experience. The results of such planning are predictable because they are based on solid knowledge rather than assumptions.

Compared with strategic planning, operational planning is easier for engineers to accomplish because past experience and examples are usually available as references.

2.3 Who Should Do the Planning?

Planning is best accomplished by those who have direct knowledge of the specific subject matter involved. In the past, strategic planning was accorded emphasis and attention by the top management of an enterprise. Company after company set up high-level corporate planning departments made up of full-time planners to devise business strategies. This approach failed to generate the expected business results. As documented in the literature, one of the key weaknesses of this approach was that the strategic planners, while being superior analysts of hard business data, were outsiders insofar as the various specific business functions (marketing, production, engineering, and procurements) were concerned. What was not apparent at the time was the fact that planning new strategies for the future required both hard data and intuitive assumptions. The success of the decision to introduce assumptions, and the extent to which these assumptions could be validated, depended very much on the planner's hands-on management experience, intuitive know-how, and in-depth insight of the specific business activities involved. As such, many plans devised by these strategists were poor. Furthermore, business managers in operating departments did not wholeheartedly embrace the plans envisaged by these outsiders. Since then, many companies have abolished their corporate strategic planning departments altogether and have reassigned this important planning function to the leaders of the business units themselves.

The moral of the story is that the most effective way of creating strategic plans for specific businesses or activities is to entrust such planning to those who are intimately involved with the particular businesses and activities. This paradigm is consistent with the empowerment doctrine, being the current industrial best practice, whereby decisions are delegated downward to lower-level persons who have direct knowledge and in-depth understanding of the subject matter at hand.

2.4 Inexact Nature of Strategic Planning

Strategic planning requires an immense amount of critical thinking (Spender 2014). It also involves synthesis that likewise requires intuition and creativity. Performing strategic thinking will bring about an integrated perspective of the enterprise, a foresight—albeit not too precisely articulated—of the company's direction that is built on insights from experience as well as hard data from market research, as it is based on learning by people at various levels involved in conducting specific business activities. Strategic planning invents new categories rather than rearranging existing ones, and synthesizes experience to move the company in a new direction. Managers should encourage others to join in the journey and to shape the company's course, thus creating enthusiasm along the way. Broad participation is therefore strongly advisable.

Strategic planners use various kinds of inputs. Study after study has shown that, in addition to hard data, the most effective managers rely on soft information—gossip, hearsay, and various other intangible scraps of information—to develop plans. A key part of strategic planning is to create a vision for the company of what the company aspires to be. To formulate such a vision, the planners must be able to "see." This is only likely when they are willing to get their hands dirty digging for ideas and extracting the strategic messages from them. Collecting these ideas as building blocks is instrumental to the development of useful strategic plans. Sanford Weill said insightfully, "Details create the big picture."

Once information becomes available, strategic thinkers comprehend it, synthesize it, and learn from it. They test ideas and verify the convergence of ideas before they define new strategies. Sometimes, strategies must be left in flexible forms, such as broad visions, in order to adapt to a changing business environment.

Strategic planning may be undertaken following a "discovery-driven approach" (McGrath 2010). In situations involving the definition of the company's future direction, most planning inputs are based on assumptions about the future. Because the ratio of assumptions to facts is usually high, the success rate of the resulting plans is typically low. Therefore, strategic planning should be a continuous process and not a single task or event to be taken care of at well-defined milestone dates. It involves constant learning, acquisition, and interpretation of hard data and soft information, as well as staff discussions related to operational feasibility, resource allocation, and performance management. Strategic planning requires the discipline of systematically identifying and validating key assumptions introduced in the planning. As more data and knowledge are discovered, more assumptions are validated to form an increasingly solid knowledge base for updating the planning. Strategic planners should engage many participants at various levels to benefit from the relevant corporate expertise and broad-based perspectives available.

The major difficulties of strategic planning can be traced back to three inherent characteristics of such planning:

1. *Prediction of the future*: Certain future events are more predictable than others; for example, seasonal variations of weather and election-year cycles. Other predictions, such as the forecast of discontinuities—technological innovations, price

increases, changes in governmental regulations affecting marketplace competition, geopolitical turbulences, and so on—are virtually impossible to predict accurately.

2. *Applicable experience and insight*: Strategies cannot be detached from the subject involved. Planners must have in-depth knowledge and relevant hands-on experience of the subject at hand in order to set forth useful strategies.
3. *Random process of strategy making*: The strategy-making process cannot be formalized, as it is not a deductive, but a synthesis process.

Studies have shown that strategic plans often fail due to one or more of the following seven reasons:

1. Not thinking strategically; for example, by limiting the strategy only to the short-term needs and processes of the company.
2. Failure to identify critical success factors for the company.
3. Not having both an internal and an external focus.
4. Lack of long-term commitment from company management.
5. Reluctance of senior management to accept responsibility for tough decisions.
6. Not leaving enough flexibility in the plans, thus causing difficulties in adjusting to the changing environment.
7. Failure to properly communicate the plan and thus not securing support and management buy-in.

It is advisable for those STEM professionals, who are involved in strategic planning, to avoid being affected by these failure factors.

2.4.1 Methods Used to Plan Strategically

In adopting strategies, companies choose what to do and what not to do. Strategizing is about making choices. In general, managers use three methods to make choices (Gavetti and Rivkin 2005):

1. *Deduction*: Based on data, managers invoke general administrative and economic principles to a specific situation, weigh alternatives, and make rational choices. This method needs a lot of data, and is useful for mature and stable industries.
2. *Trial and error*: Experiment with several options and select one. This is good for ambiguous, novel, or complex situations in order to experiment and learn from the experience.
3. *Analogies*: Various strategies are made by analogies. Decision-makers often need to think back to a familiar situation, draw lessons from it, and apply those lessons to the current situation. However, making decision by analogy must be done carefully.

Using analogies, managers pay attention to selected features of a situation, as opposed to every aspect. The case study method works toward building students' analytical thinking based on past experience in order to enable the transfer of lessons from one industry to another. To maximize the effectiveness of the analogy method in strategic thinking, managers must be able to recognize similarities along dimensions that truly drive business performance, and not be fooled by superficial similarities between sources and targets. There are four ways to avoid superficial similarity when practicing analogies:

1. *Recognize the analogy and identify its purpose*: Is there an analogy between the source and the target to allow the target to contribute to a desired purpose?
2. *Understand the source (old case)*: Define the environment, the solutions that worked well in that environment, and the link between the environment and the winning strategy. Then, check if the relationships discovered here applied to the target environment.
3. *Assess the similarities and differences between the sources and the target*: Are the similarities only superficial? Do the similarities exist along critical dimensions (e.g., dimensions that drive economic performance)?
4. *Translate, decide, and adapt*: Decide whether the original strategy, properly translated, will work in the target situation.

Other uncertainties that impede analytical reasoning are emotional attachment to an early choice and the halo effect—decision-makers seek out supporting evidence and ignore conflicting data (e.g., confirmation biases). The best approach of strategy planning involves using all three methods (deduction, experimenting, and analogy).

Example 2.1

The method of analogy is important for developing strategic thinking. How can this method be applied systematically and in a rational manner to minimize its potential misuse?

Answer 2.1

The following rational method may be useful when applying the analogy methodology in strategic planning:

1. List dimensions that characterize the source case, and which represent the past known case. The solution to the past case is to potentially apply the present case, the "target case." One such dimension is "linkage between solution and the achieved success in the past case." It is important that such linkages exist between cases in order to justify the use of the past case solution.
2. In describing the past case, classify the dimensions as "major" or "minor."
3. List some key attributes of the past case in each dimension.
4. Evaluate the present case in each of the listed dimensions in terms of relevant attributes.
5. Compare the attributes of the present case with those of the past case.
6. Assess the degree of similarity and difference between the two.
7. Enter the result in the last column, "similar," "somewhat," or "no." Of course, it is crucial that the major dimensions are assessed correctly. If they are deemed similar, then the present case can be determined as possessing a "deep similarity" with the past case.
8. Apply the solution to the past case as the strategic solution to the present case, only if a similarity is sufficiently established (see Table 2.1).

TABLE 2.1

Rational Method of Applying Analogy in Strategic Planning

Dimension	Major/Minor	Source Case (Attributes)	Target Case (Attributes)	Is Target Similar to Source?
1	Major	(a,b)		Yes
2	Major	(c,d)		Some-what
3	Major	(e,f)		No
4	Major	(g,h)		Yes
5	Minor	(i,j)		Maybe
6	Minor	(k,l)		No

2.4.2 Technique to Gain Strategic Insights

Companies must consider the external environment, such as customers and competition, when they plan strategically. Ubany and Davis (2007) offer a special "Three Circles" technique to deepen strategic insights (see Figure 2.1).

Let us draw three circles, one for a customer's needs, one for a company's offerings, and one for a competitor's offerings. When a company's or a competitor's offerings match with a customer's needs, these circles overlap. Specifically:

A: Area representing our advantages. How big and sustainable are our advantages? Are they based on distinctive capabilities?

B: Area designating points at parity. This area indicates that we are on par with our competitors. Are we delivering effectively in the area of parity?

C: Areas depicting our competitor's strength. How can we counter our competitor's advantages?

E: White space. This is the area for growth. Ask customers how our strengths can be made useful to them?

D, F, and G: Areas denoting values produced by the company and the competitors that the customers do not need.

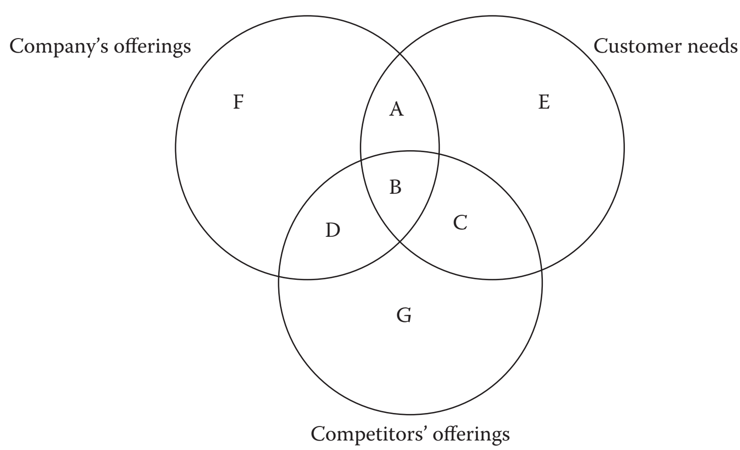

FIGURE 2.1
Strategic insights in three circles.

A key planning question to ask is: How can we devise strategies that would increase area A, while reducing D and F.

2.5 Planning Roles of Engineering Managers

Engineering managers at the middle and low levels will predominantly devise operational plans to achieve the short-term goals of the unit or department. As engineering managers move up the corporate ladder, they are expected to participate increasingly in strategic planning, with emphasis placed on technology, product, and production planning. They may find it useful to follow the planning guidelines listed next, in order to add value to the company.

It is important that engineering managers spend time and effort to actively assist their direct superiors in planning. These tasks may include (1) analyzing hard data (industry, competition, and marketing); (2) offering alternative interpretations of the data available; (3) raising insightful questions to challenge conventional assumptions; and (4) communicating the resulting outputs of planning—programs, schedules, and budgets—to help effectuate buy-in from others.

To optimally benefit from the knowledge, expertise, and insights of staff, engineering managers are encouraged to engage their staff and other employees in the planning activities.

It is quite self-evident that engineering managers need to perform a number of planning tasks:

2.5.1 Time Management

All managers need to plan and prioritize their personal daily tasks (such as problem solving, staff meetings, task specification, progress monitoring, and performance evaluation), according to the value each task may add, so that high-value tasks are completed before others. This is to maximize the value contributed by their daily activities (Feddox 2014). Also to be included in the daily to-do list are tasks such as networking, continuing education, and scanning emerging technologies, which are deemed important for advancing one's own career.

2.5.2 Projects and Programs

Engineering managers need to plan projects and programs assigned to them by upper management. In doing so, they need to fully understand the applicable project objectives, the relevant performance metrics used to measure outcome, and the significance of this outcome to the company. They should carefully select staff members with the relevant skills, expertise, and personality to participate in the project and seek their inputs regarding tasks, resource requirements, preferred methodologies, and task duration. They should then integrate all inputs to draft a project plan and distribute the plan among all participants to iteratively finalize the relevant details. These details include budgets, deliverables, and dates of completion. Managers must also secure authorization from upper management before initiating work related to the projects and programs.

2.5.3 Corporate Know-How

The preservation of corporate know-how is of critical importance to the company for maintaining and enhancing its competitiveness in the marketplace. Corporate know-how comes in many types and forms. Certain documentable knowledge, such as patents, published memoranda, operational manuals, and troubleshooting guides, is easy to save. Others, such as insights related to procedures or perfected ways of designing the specific products and services of the company, may require extra efforts to preserve. Managers should plan to systematically capture, retain, and widely disseminate such know-how to maximize its use within the company. Certain other cognitive knowledge is typically retained mentally by the experts. Managers need to find effective ways to induce such experts to willingly externalize this tacit knowledge for use by others in the company.

Problem-solving expertise is yet another type of corporate know-how worth preserving. Typically, engineering managers are busy resolving conflicts that may arise from disagreements in task priorities, personality conflicts, customer complaints, interpretation of data, and other conflicts. Managers need to solve these problems promptly. They should be mentally prepared to jump from one task to another to handle such time-sensitive issues. What should be planned under these circumstances is the preservation of the learning experience garnered from each incident so that the company will become more efficient in solving similar problems in the future.

2.5.4 Proactive Tasks

Engineering managers should plan to devote their efforts to proactively pursue certain other tasks. These tasks include

- Utilizing new technologies to simplify and enhance the products and services of the company.
- Creating business networks and searching for partners to form mutually beneficial alliances.
- Offering new or enhanced services to customers (e.g., self-service, an information-on-demand system, and an Internet-based inquiry center).
- Initiating new programs to promote healthy customer relationships.
- Developing novel products/services with distinguishable attributes (e.g., product customization to serve customers better, cheaper, and faster).
- Reengineering and simplifying specific operational processes to increase efficiency.
- Outsourcing specific tasks to augment cost-effectiveness and to reduce time to market.

2.6 Tools for Planning

Engineering managers utilize a number of tools to prepare strategic plans. Some of these tools produce hard data, whereas others offer qualitative insights into specific subject areas (ASQ Quality Press 2011). The following are examples of some useful planning tools:

2.6.1 Market Research

Market research applies a number of tools to discover the preference of customers with respect to the company's products, services, marketing strategy, product prices, competitive strengths, and brand reputation in the marketplace. Examples of such tools include polling by questionnaires, product concept testing, focus groups, and pilot testing. The outputs of market research help assess the company's current marketing position and future growth opportunities in the marketplace (Burns and Bush 2013; Malhotra 2014).

2.6.2 SWOT Analysis

SWOT is the abbreviation for strength, weakness, opportunities, and threats. Each company has strengths and weaknesses in comparison to its competitors (Mcguire 2014). Because of the company's strengths or core competencies, there may be opportunities offered in the marketplace that the company ought to exploit aggressively. On the other hand, because of the strengths of its competitors and the conditions in the marketplace, the company may be subjected to certain future threats. Such potential threats could be the result of technology advancement, business alliances, marketing partnerships, and other such step changes accomplished by the competition. New governmental regulations and policies may also affect the company's business in the future.

A systematic monitoring of publications—patents, technical articles, news releases, and financial reports—represents an initial step in conducting a competitive analysis. A well-performed SWOT analysis will bring to the fore an assessment of the company's current position. As such, the SWOT analysis procreates a road map by which a company can make informed decisions about improving its core competencies to meet its current and future business and operational needs. The analysis answers questions such as (a) What does the company have in place today? (b) In which direction is the company headed in the next three to five years, and (c) What is the company's process of managing changes?

2.6.3 Financial What-If Analysis and Modeling

Spreadsheets are useful in modeling the financial performance of an operation. Financial statements (such as an income statement, balance sheet, and funds flow statement—see Section 7.3) are usually modeled in a spreadsheet program. *What-if* analyses are readily performed to discover the sensitivity of the company's financial performance relative to the changes of specific input variables. In addition, such analyses permit the verification of various assumptions incorporated into the financial models (Ragsdale 2014).

Most businesses have inherent risks due to the unpredictable nature of the business climate, the liquidity of financial markets, certain governmental regulations and international trade policies, currency stability, customer preferences, competition in the marketplace, disruptions induced by new technologies, and other factors. What-if analyses and Monte Carlo simulations (see Section 6.4) may be applied to assess the impact of some of these risk factors on a company's business.

2.6.4 Scenario Planning

Scenario planning defines the major forces that may move a company in different directions, maps out a small number of alternatives futures (scenarios), defines narratives to describe these scenarios, and develops options for managing within these future worlds

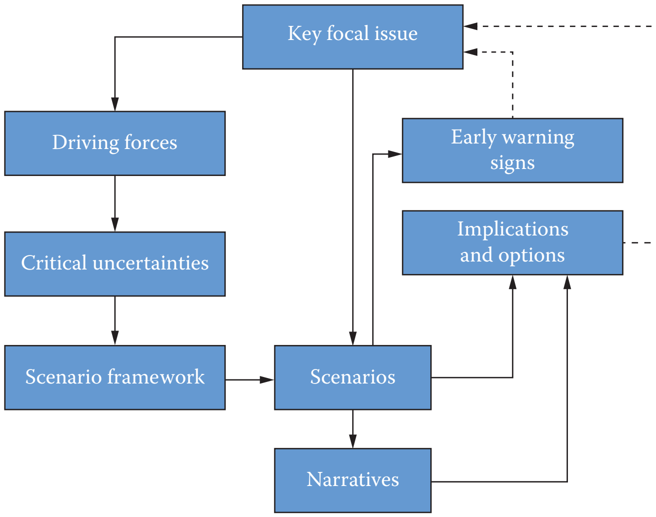

FIGURE 2.2
Scenarios planning process.

(Garvin and Levesque 2006). Figure 2.2 shows the scenario planning process involving a number of components.

The key focal issue represents a significant upcoming decision or a strategic uncertainty. The driving forces are themes and trends that are most likely to influence the key focal issue in fundamental ways. Examples include social dynamics, economics, political affairs, and technology. Some of these driving forces are more important than others. The top two and most influential of these driving forces represent critical uncertainties. Using critical uncertainties as axes, a 2 × 2 map, the scenario framework, is created. This 2 × 2 map defines four quadrants, the four futures, which will influence a company's future directions. Each of these four scenarios is then written up as a story. Planning participants then deliberate on the implications of these four stories with respect to the key focal issue at hand. This group's deliberations will likely result in the identification of the company's strengths and weaknesses, as well as define strategic options for future directions. Early warning signals are leading indicators that highlight the likely emergence of one scenario or another. These signals must be constantly monitored in order to initiate a strategic reevaluation.

Why do we limit ourselves to only two critical uncertainties in the scenario planning process? This is possibly because business people will typically use two-dimensional diagrams (2 × 2 maps), which are easily transposed onto paper to describe product positioning, product classification, and business-related issues. Engineers are capable of envisioning three-dimensional diagrams. Thus, the aforementioned concept could be easily extended to three key uncertainties, providing a total of 8 (=2^3) scenarios for possible consideration when each future is affected by three uncertain driving forces. Three uncertainties are more realistic than two in evaluating the future of businesses. Molecular physicists are trained to define the "state" of molecules by seven variables, namely, three spatial coordinates, three velocity components, and one time variable. They typically think in seven-dimensional space and use a seven-dimensional distribution function to define the state of a molecule. Thus, one can easily envision a scenario defined by seven (not two) uncertainties, offering many more scenarios for consideration. Engineering managers should try

TABLE 2.2

Eight Scenarios Based on Three Critical Uncertainties

#	Uncertainty 1	Uncertainty 2	Uncertainty 3
1	High	Low	Low
2	High	High	Low
3	Low	Low	Low
4	Low	High	Low
5	High	Low	High
6	High	High	High
7	Low	Low	High
8	Low	High	High

to use at least three key uncertainties for scenario planning. Table 2.2 shows eight futures influenced by three uncertainties.

As pointed out by Schoemaker (1995), scenario planning can capture a whole range of possibilities in rich detail. It is a disciplined method for imagining possible futures. Scenario planning reduces a lot of data into a limited number of possible states. Each scenario tells a story about how various factors interact. Scenario planning is different from the following:

1. *Contingency planning examines only one uncertainty*: What if we don't get the patent? Contingency planning starts with a base case and considers an exception to it (what-if analysis). Scenario planning, on the other hand, explores the joint impact of *various uncertainties* that take place concurrently. It tries to determine the new state, as a result of the concurrent changing of several independent variables.
2. *Sensitivity analysis examines the effect of a change of one variable*: While keeping all other variables constant. This approach is effective for monitoring small magnitude changes in order to determine new states.
3. *Not the same as complex computer simulations*: Scenarios can include elements that cannot be modeled, such as subjective judgments.

Whenever the future needs to be assessed, scenario planning is applicable. It applies generally to decision-making under uncertainty. The methods of developing scenario planning include the following:

1. Define the scope
2. Identify the major stakeholders
3. Identify basic trends
4. Identify key uncertainties
5. Construct initial scenario themes
6. Check for consistency and plausibility
7. Develop learning scenarios
8. Identify research needs

9. Develop qualitative models
10. Evolve toward decision scenarios

Scenarios should describe generically different futures rather than variations on one theme. Schoemaker's (1995) article contains an example of scenario planning for an advertising agency.

Garvin and Schoemaker (2006) pointed out that "there is no right or wrong scenario." Scenario planning has a number of advantages and disadvantages. The advantages are

1. Prepares managers for multiple, alternative futures.
2. Creates a common vocabulary.
3. Encourages strategic conversations.
4. Forces managers to articulate critical uncertainties.
5. Considers the interactions between these uncertainties and the likely implications.
6. Legitimizes divergent ways of thinking that are essential for success.

What are some of the disadvantages of scenario planning? These could include:

1. Is scenario planning no more than "pipe dreams and happy talk?"
2. Does it encourage wishful thinking and lead to a desire for one particular future and outcome?
3. Is the absence of a tight link between scenario planning and formal goal setting and action planning a cause for concern?

2.6.5 Performance Benchmarks

Performance benchmarks are those that have been successfully applied by successful firms in the same or a related industry. When undertaking planning activities, it is important to define these benchmarks for the purpose of measuring corporate progress. Hubbard (2014) offers an excellent set of broad-based benchmarks, which include:

1. *Customer-related measures*: Product defects, just-in-time delivery, life-cycle product cost, customer satisfaction score, order processing efficiency, percentage sales from new customers, service quality, time taken between orders and product delivery, and so on
2. *Process-related measures*: Time to market (i.e., the lapse of time from the initiation of product design and development to product delivery to the marketplace), quality standards, unit product cost, core competence development, labor hours per product, and so on
3. *Financial measures*: Gross margin, net income-to-sales ratio, current ratio, sales per employees, return on equity, sales growth rate, market share percentage, inventory turn ratio, and so on
4. *Employee-related measures*: Turnover ratio, employee satisfaction score, skill building and development expenses per employee, and so on
5. *Competition-related measures*: Market share, cost of innovation, acquisition cost per new customer, number of new products commercialized per year, and so on

A large number of these quantitative metrics are available either from the financial statements of the companies in the same industry or from public sources such as (1) banks that offer loans to companies in a specific industry, (2) financial institutions that analyze and compare companies' performance on behalf of investors, and (3) service organizations that offer the credit ratings of firms seeking debt financing.

These metrics serve well as industrial benchmarks against which to assess the current status of a specific company and to define its new strategic direction.

Example 2.2

Quality is usually defined differently by different people in a company. Explain why. Which quality definition is the correct one for the company to adopt?

Answer 2.2

Different people in a company may have different interests and perspectives in defining quality. Examples are shown here:

1. *Production*: Quality is the reject rate and deviation from specifications (view of a production engineer).
2. *Value based*: Quality is defined in terms of price and costs (view of a marketing person).
3. *User based*: Quality is the degree to which a product satisfies the customer's needs. Customers do not appreciate less or more quality than they need (view of a customer).
4. *Product based*: Quality is related to the number of attributes offered by a product (view of a product designer).

For the company to succeed in the marketplace, quality is in the eyes of the beholder. The user-based definition is preferred.

2.6.6 Technology Forecasting

Technology forecasting is of critical importance to those companies whose products are composed of high-technology components. Companies must constantly examine, monitor, and apply emerging technologies to enhance business performance. (Porter et al. 2011). Engineering managers need to understand the value that any of these emerging technologies (e.g., big data, cloud computing, the Internet of Things, mobile communications, and social media practices), may have on the products and services offered by their employers and plan accordingly.

Another technological example is the speed of computing. It is almost a certainty that the computing speed will continue to increase over time. The question for engineering managers is as follows: How can business benefit from such advancements? Computing speed may be used advantageously in computationally intensive problems, whose solutions of finer granularity provide value to the business. Here are several examples that illustrate how a refined granularity can help:

1. Data mining applications related to customer relations management may be of direct benefit to business. Assuming that customer data (e.g., prices paid, items bought, purchasing habits, and payment methods) are collected and available, a detailed analysis could lead to an in-depth understanding of customer behavior, not available heretofore, thus allowing companies to structure customized selling

and marketing programs to achieve better customer satisfaction, enhanced brand loyalty, and improved company profitability.

2. Refined modeling of key components in turbomachinery (e.g., compressors, blowers, and pumps) by using computational fluids dynamics programs could raise aerodynamic performance and reduce energy consumption.
3. Plant operations groups typically have accumulated a significant amount of data, observations, and experience in maintaining and troubleshooting equipment and facilities. Such information is dispersed widely, difficult to redeploy, and remains useless. A data mining application could help in getting the information organized and ferreting out valuable knowledge from the wasteful piles of raw data. The application of such knowledge could lead to productivity enhancement in plant operations.
4. Sophisticated computer models could be devised to impact-test automobiles, instead of crash-testing expensive vehicles at speeds of up to only 40 miles/hour, in order to design better, safer, faster, and cheaper cars.

It is quite certain that engineering managers will be able to envisage many other computationally intensive problems that can be processed to reap business benefits.

2.6.7 Product Life-Cycle Analysis

Every product has a life cycle that moves typically through the stages of initiation, growth, market saturation, and decline (Kloepffer and Grahl 2014). Engineering managers need to examine the life cycles of all products marketed by their enterprises. Doing so will guide them in introducing new products or product enhancements in a timely manner in order to sustain company profitability.

Tools for operational planning include the following: Microsoft Project 2013, Enterprise Project Management Timeline, critical path method (CPM), program evaluation review technique (PERT), and others listed in Section 12.2.2.

2.7 Planning Activities

The activities of planning involve strategic and operational planning. Strategic planning requires forecasting, action planning, and issuing policies. Operational planning necessitates action planning, issuing policies, and establishing procedures. Some planning activities are proactive, others are reactive in nature.

2.7.1 Forecasting

The objective of forecasting is to estimate and predict future conditions and events. All forecasting activities center on assessing future conditions in technology, products, marketplace, and other factors affecting the business success of the company (Ray 2015; Hyndman and Athanasopoulos 2013). The marketplace revolves around customers, competition, economy, global supply chains, human resources, capital, and facilities.

Forecasting helps to define potential obstacles and opportunities. It sets boundaries for possibilities to help focus on specific future conditions, define worthwhile objectives, promote intergroup coordination, provide the basis for resources allocation (manpower, budget, facilities, and business relations), and induce innovation through forecasted needs (Zhu and Fung 2010).

Forecasting may be implemented by using the following steps:

1. *Identify*: Critical factors that have the most profound effects on the company's profitability.
2. *Determine*: The forecasting horizon as short term (1 year), intermediate term (2–5 years), or long term (5–10 years).
3. *Select*: Forecasting methods such as
   a. Mechanical projection. The future is projected assuming essentially the same characteristics as in the past.
   b. Analytical projection. The future is estimated based on an extrapolation of the past (trend analysis). Statistical tools such as linear or nonlinear regression, moving averages, exponential smoothing, time series, and others may be applied.
4. *Forecast*: Future eventualities and their likelihood of occurrence.
5. *Prepare*: The forecast, as well as the pertinent database.
6. *Adjust*: Forecasts regularly to incorporate pertinent changes related to assumptions and desirable results.
7. *Ensure*: Understanding and acceptance by all parties affected by the forecast.

Several observations are worth noting. Major economic events such as prices, wages, raw materials, and so on tend to change gradually. The farther an event is projected into the future, the greater the probability of significant deviations between the forecast and reality. Certain future events tend to result from current and past occurrences, as long as there are no disruptive changes in technology or society, such as wars, natural disasters, or major incidents. The future may be planned with detailed, factual knowledge of the present and the past under those conditions. It is important to screen ideas by using proper criteria that are consistent with the company's objectives, technical capabilities, financial viability, and marketplace compatibility. Useful inputs may be offered by customers, salespeople, production employees, service clerks, and others who possess intimate knowledge of specific subjects.

Engineering managers are likely to get involved primarily in technology forecasting. As discussed before, forecasting the impact of new technologies on future businesses is particularly difficult. For example, in the past, few companies understood the significance of the Internet to company operations and the marketplace. Questions like those enumerated next did not have clear answers:

1. What will be the impact of broadband technology (cables, optical networks) to communications?
2. How will nanotechnology affect engineering activities such as product design and equipment operation in the future?
3. Will the next wave of new products be smart appliances and intelligent devices?

4. What happens if processors get more powerful and intelligent devices get smaller and more mobile?
5. What about the molecular switching devices that Hewlett-Packard is said to be working on that could lead to computational devices about one million times smaller than those we have today?
6. What will be the impact of "pervasive computing," "big data analytics," "cloud computing," "mobile computing," and "open innovations" on consumer markets?
7. How quickly will personal computers (PCs) lose their market value, once alternative devices that allow customers to access the Internet, get and send messages, purchase goods and services, activate entertainment programs online, and control home appliances remotely become widely available?
8. How will the new technologies related to intrinsic and extrinsic smart materials, which exhibit sensing and other capabilities, impact on the industrial product design in the future?

To forecast the impact of new technologies, engineering managers must be properly prepared. Some business researchers portend that people with broad perspectives and variable professional experience and exposure may have a better chance of accurately forecasting the impact of emerging technologies, market trends, and other future conditions that require "foresight." Teams whose members have diversified backgrounds in engineering, product design, manufacturing, marketing, service, and sales are said to be better equipped in handling technology forecasting that could benefit from the divergent experience and insights of composite teams.

Engineering managers whose backgrounds are broad-based are likely to be more successful in technology forecasting if they are supported by teams that also have diverse experience.

Example 2.3

The U.S. economy is shaped by a number of factors. The ongoing conflicts in the Middle East and associated global anxiety rankle the business environment and influence employment and consumer spending. Correctly reading trends in the economy can make or break a business. Where can an engineering manager find data that could help predict the direction of the economy?

Answer 2.3

There are leading and trailing indicators for the economy. The 2008–2009 U.S. recession differed from others in its cause, severity, and scope. According to a recent assessment published in the literature, many of the commonly used indicators did not forecast well. These indicators include stock prices, unemployment claims, housing starts, orders for new capital equipment, and consumer sentiment.

Gene Sperling, who served as director of President Clinton's Council of Economic Advisors, offers some advice for business leaders to get ahead of the competition by becoming their own economists (Sperling 2003). Specifically, he suggests that the following set of indicators be used: (1) CEO opinions, (2) temporary jobs, (3) consumer spending, (4) bank loans, (5) semiconductors, (6) commercial structures, and (7) housing markets.

2.7.2 Action Planning

Another important activity related to planning is action planning, which is the process of establishing specific objectives, action steps, and a schedule and budget related to a predetermined program, task, or project (Kerzner 2013). Action planning helps to focus on critical projects that need attention and action. The identification of critical projects enables the company management to pay attention primarily to planning for deviations that may arise—the principle of management by exception. Furthermore, action planning states specific results to be accomplished. Defining results to be accomplished requires the planner to make judicial selection and exercise judgment. In addition, action planning provides standards as milestones that facilitate control and clarify accountability for results. It also permits an effective delegation of responsibilities (who is responsible for what results), encourages teamwork, and ensures an evaluation of the overall performance of the program, task, or project on a continuous basis.

Action planning mandates engineering managers to take the following specific steps:

1. *Analyze critical needs*: Critical needs are those associated with staff development, staff maintenance, and staff deficiency, as well as those related to special assignments. Managers define these needs by reviewing standards related to position charters, duties, management expectations, and company goals. Short-term needs must be in balance with long-term needs.
2. *Define specific objectives*: Specific objectives need to be defined to satisfy the critical needs. The results statement (who will attain what desirable results by when) must be specific. Establishing objectives predetermines the results to be accomplished.
3. *Define standards*: Standards measure the attainment of the objectives. The standards should preferably be quantitative in terms of performance ratios, percentages, cost figures, resource parameters, and other factors in order to be measurable (Kaplan and Norton 1996).
4. *Define key action steps*: The definition of key action steps establishes the sequence and priority of steps required to attain objectives. Specifically, major steps are lined up in the order in which they are to be performed; this list includes the evaluation of risks for the steps planned, the definition of contingency steps to ensure the expected results, and the specification of who is responsible for each step and who is accountable for achieving the target value associated with each step.

   Action steps must be reasonably implementable. After the expected results are defined, engineering managers should plan these steps with the active participation of the workers involved to benefit from their creativity and expertise in the subject matter.
5. *Create a schedule:* Scheduling establishes both a time sequence for action steps and the interrelationship among the steps, as some might be prerequisites for others. It is advisable to estimate the optimistic (earliest), the pessimistic (latest), and the most likely (most probable) dates of possible completion of each step. Doing so will permit a more realistic modeling of the project schedule.

   Sufficient scheduling flexibility should be included to account for contingency—more for projects related to new development and less for routine design and analysis work. Contingency refers to the slag and cost buffers introduced to account for undefinable, yet generally anticipated, deviations from the plan.

   The most important outcome of the scheduling effort is the definition of the project or program completion date. The engineering manager, as the leader, is accountable for completing the project or program on time.

6. *Develop a budget*: Budgeting allocates resources necessary to accomplish project objectives. The planner determines the basic units (man-hours, man-weeks) to accomplish each task, estimates the total resources needed for the project, and adds a contingency to the total amount for potential deviation (e.g., 7%–10% of the total budget, dependent on the customary percentages used in each industry) to arrive at a total budget.

The budget estimate is typically the basis for seeking management approval for the project or program. The project leader is accountable for completing the project or program within the approved budget.

For complex projects that involve many participants (e.g., peer departments, external suppliers, and outsourcing service organizations), project management tools such as PERT or CPM may be applied. These tools produce time lines, graphically diagram the tasks network to facilitate monitoring and control, and determine the tasks linked along the critical path. Consequently, the shortest time in which the project can be completed can be determined. Managers are then reminded to monitor these critical path tasks carefully in order to avoid project delays.

A well-developed project plan serves the purpose of promoting communication, monitoring progress, evaluating performance, and managing knowledge.

2.7.3 Issuing Policies

For companies to operate smoothly and consistently, corporate rules and regulations are used to prescribe acceptable practices. Company policies address important issues such as employee hiring and termination, equal employment opportunity (EEO) policies, annual performance appraisals, savings plans, benefits, medical insurance, pension plans, sick leave, safety, contact with representatives of competitors, and other issues. At the departmental level, specific rules may be defined to regulate tasks that are repetitive in nature, such as filing reports after each completed business trip, submitting monthly or quarterly progress reports to summarize achievements and preserve new lessons learned, and outlining future work (i.e., attending scheduled staff meetings, publishing engineering or scientific articles, participating in professional and technical conferences), and other tasks.

Managers may write policies to offer uniform answers to questions of common concern. In general, policies are continuing directives promulgated to address repetitive issues, tasks, and problems in an organization. Policies are useful for predeciding answers to basic repetitive questions, capturing the distilled experience of the organization, saving management time, and facilitating delegation. Issuing policies is a part of the manager's planning responsibilities.

To be effective, a policy must have certain common characteristics, such as: (1) applies uniformly to the organization (or specific engineering unit) at large; (2) remains relatively permanent, unless and until repealed; (3) fosters the objectives of the company; (4) frees managers and employees to focus on important matters; (5) encourages effective teamwork by reducing disagreements, conflicts, and differences in interpretation; and (6) is issued by top management or authorized managers with perspective, balance, and objectivity.

2.7.4 Establishing Procedures

Companies perform many important tasks such as product design, plant operation, project management, equipment installation, facility maintenance, manufacturing, system engineering, parts procurement, product delivery, customer service, and others. The specific methods by which these tasks are performed represent the valuable corporate know-how employees have learned to perfect. Over time, companies want to preserve these "tried-and-true" procedures in manuals.

Developing procedures is of critical importance to a company, not only because doing so will preserve the best way to perform repetitive work (to achieve high productivity), but also because doing so will accomplish the following: (1) provide the basis for method improvements; (2) ensure standardized action (such as quality control, resource saving, and work reproducibility); (3) simplify training; and (4) retain corporate memory, such as know-how, insights, knowledge, heuristics, proven safety practices, problem-solving techniques, and so on.

Establishing and preserving procedures is part of the planning responsibility of managers. If generated in suitable formats, such procedures could be widely applied within the company and among its business partners to garner competitive advantages in the marketplace. Techniques for developing procedures include

1. Concentrating on procedures for critical work that is in high demand, repetitive, and time-consuming.
2. Charting graphically the work required—inputs, workflow, outputs, skills, and resources.
3. Reviewing work characteristics carefully in order to decipher (a) why (is the work really necessary?), (b) what (results are to be obtained?), (c) when (is the best time to do it?), (d) where (is the best place—group, station, facility, or equipment—to do it?), (e) who (is the person with the relevant training to do it?), and (f) how (significant might be the impact of its outcome?).
4. Proposing procedures in the context of existing objectives, policies, and programs by keeping the procedures to a minimum; this will avoid restricting employee imagination and incentive, as well as ensure consistent applications to minimize deviations.
5. Defining improvements to procedures and updating them regularly.
6. Formulating the procedures in writing.
7. Communicating with all affected parties to ensure understanding and acceptance.

2.8 Some Specific Advice on Planning

Good up-front planning is essential for any company to achieve its desired corporate objectives. Managers need to pay sufficient attention to planning activities in order to make sure that certain pivotal factors are sufficiently addressed in the strategic or operational plans they formulate.

2.8.1 Assumptions

Plans are typically built on both hard data and assumptions. Assumptions are usually based on extrapolations of past experience and intuitive projections into the future. It is important for managers to constantly seek and interpret additional resources and insights to verify their assumptions. This is to ascertain that the plans they introduce are built on an increasingly solid foundation.

2.8.2 Resistance to Change

Any plan is worthless unless its objectives are achieved through successful implementation. Implementation requires dedicated people who are supportive of and ardent about the subject matter involved. Managers need to take into account the suitability of people, including their background, personality, training, mental flexibility, interpersonal skills, collaborative attitudes, adaptability, and emotional attachments to specific ways things are done.

Most plans contain activities related to a change of the current status. Unfortunately, most people resist change, particularly sudden changes. Change may induce business instability, technology obsolescence, organizational restructuring, and other unwanted disruptions. People may be more amenable to gradual changes if such changes occur at a rate that they can understand and accept.

Managing change is a challenging task for managers. Managers need to recognize early that change is coming. They may want to delineate the change in detail and analyze the implications of the change as a way of preparing the staff and allowing them to become gradually accustomed to such a change.

By paying close attention to how changes are being communicated to the staff, managers may be able to minimize the resistance to change and gain support for the implementation of new plans. It is helpful for the managers to isolate and identify areas of threats and opportunity. If needed, they should apply contingency plans for handling threats, but focus on opportunities that will advance the company business.

2.8.3 Benefit versus Cost

When planning, managers need to be guided by the expected value that a given project or program may produce. Low-value projects justify the commitment of low-level efforts, whereas high-value projects justify the allocation of high-level efforts. Efforts applied should be commensurate with the value added by the expected results. Otherwise, corporate resources may be wasted. The saying "things worth doing are worth doing well" is valid only to the extent justifiable by the expected value.

2.8.4 Small but Sure Steps

To be effective in planning, managers should (1) identify clearly the desired end results and the series of small steps required to reach them; (2) allow a timely control and midcourse correction, if needed; and (3) aim at attaining a series of small progressions (or continuous improvements) that are more acceptable in many old-style companies than one large achievement (or a step change) after a long period of time. On the other hand, some start-up companies with an entrepreneurial spirit may be able to exercise patience, take risks, and go for "blow-the-roof-off" breakthrough technologies and step-change products or services. Managers need to adjust accordingly.

2.8.5 Contingency Planning

Contingency planning represents the definition of predetermined back-up steps to take, if and when a specific action step, as originally planned, fails to deliver its anticipated outcome.

As discussed before, strategic planning for the future entails considerable risks and uncertainties. Some of the changes in future conditions are unpredictable. Yet, strategic planning for the future must be done today. Besides striving for acquiring hard data and soft information to continuously validate the assumptions introduced in the planning, managers should take an additional risk-modulating step: study exhaustively the sensitivity of various assumptions to the company business and incorporate contingency steps, including fallback positions, in order to minimize the adverse impact of questionable assumptions (Nokes 2014).

2.8.6 Commitment

Managers need to secure company commitment before any plan can be implemented successfully. Company management must declare their intentions and their readiness to allocate resources needed to achieve the planned objectives. Without a firm company commitment, nothing of value will emerge from the planning efforts.

Example 2.4

Joe Engineer took a graduate school course at SUNY-Buffalo where he learned the importance of planning. Joe knows that luck plays a big role in one's life. But he is convinced that proper planning will help him to have an orderly progression in his career. He thinks that it would be cool to become a CEO of a publicly owned, multinational company at the age of 60 and retire at 65 with a net worth of $5 million. He wants some guidance with career planning. How can you help him?

Answer 2.4

It is advisable for Joe Engineer to follow a number of planning steps, enumerated here:

1. *Set objectives and specify subgoals:* Before starting the planning process, we need to introduce an important assumption. In order for Joe Engineer to be entrusted with a given management position in a publicly held major company, he needs to have acquired and successfully demonstrated certain business management capabilities beforehand. Obviously, this assumption may not be valid for small and medium-sized companies that are privately held.

   The CEO of a major company must be familiar with many functional areas, such as (1) strategic management, (2) business management, (3) operational management, (4) project or program management, (5) engineering management, (6) production and manufacturing, (7) marketing management, (8) financial control, and (9) globalization. The future CEO must be able to demonstrate sufficiency in various skills, such as

   a. Public speaking and writing
   b. Business analysis and planning
   c. Public relations
   d. Problem solving and conflict resolution
   e. Interpersonal skills
   f. Negotiations
   g. Business relations development
   h. Other skills

   Therefore, for Joe Engineer to qualify for the CEO job, he must have garnered useful management experience, possibly as a company president a few years back. Future capabilities are, by and large, based on past experience.

Applying such a logic in a backward-chaining manner, Joe Engineer could readily establish a set of milestones in his plans:

a. Corporate president at 55
b. Division president at 50
c. Vice president at 45
d. Director at 40
e. Manager at 35
f. Supervisor at 30
g. Group leader at 25

2. *Develop action plans:* A forward chaining plan, which moves from the present to the future, should be considered by Joe Engineer. As examples, the following plan illustrates the qualifications that should be built up when advancing from one stage to another:
   a. Preparation (by a certain date)
      i. Take steps to collect pertinent career development references and acquire perspectives.
      ii. Talk with experienced engineers to obtain insights related to the costs and benefits of the targeted objectives. The advantages and disadvantages of being a manager are well known: power, prestige, and money versus travel, 50–60 hour workweeks, job pressure, office politics, balance between work and home, and related factors.
      iii. Understand one's own career objectives and the requirements to succeed. What are the "success factors" involved?
      iv. Be aware of one's own strengths and weaknesses, personality type, value system, personal requirements for happiness.
      v. Confirm desirable objectives of moving into the managerial career path.
   b. Group leader
      i. Get a master of engineering degree to demonstrate technical competence (by a certain date).
      ii. Become well versed in engineering management concepts and practices (e.g., take courses or training).
      iii. Practice good interpersonal skills by doing volunteer work.
      iv. Network inside and outside the company (join technical societies, attend technical conferences, publish technical papers, etc.) and know some professional people well.
   c. Supervisor
      i. Seek training on supervision and practice teamwork with dedication.
      ii. Take advanced technical courses, if needed, to help become established as a technical leader.
      iii. Broaden into marketing, production, and sales through business interactions.
      iv. Function as a gatekeeper for technology.
      v. Demonstrate innovative capabilities.
      vi. Continue networking and become known to many others inside and outside the company.
      vii. Attain recognizable technical achievements.
      viii. Demonstrate managerial potential.
      ix. Become known as a good problem solver.
   d. Manager
      i. Demonstrate prowess in strategic planning, operation, and all other engineering management skills.
      ii. Demonstrate capabilities in interacting with sales, marketing, production, service, and customers.

  iii. Show success in initiating and implementing new technology projects that affect the business success of the company.
  iv. Achieve organization-wide recognition.
  v. Form networks with decision-makers at various levels.

e. Director
  i. Become widely known in one's own industry.
  ii. Participate actively in industrial trade and technical conferences.
  iii. Demonstrate leadership in strategic planning affecting the company.
  iv. Be recognized for operational efficiency.
  v. Make major contributions to direct the company's businesses.
  vi. Master the technology–marketing interface.
  vii. Lead the company in applying emerging technology to constantly strengthen competitiveness.
  viii. Represent the company well to the press.
  ix. Have real friends in high places.

f. Vice president

Joe Engineer is encouraged to fill in the remainder of this plan as an exercise.

3. *Budget and commitment*
   a. Invest the proper amount of resources (time, money, and effort) to ready oneself for the next stages.
   b. Make a firm commitment to carry out the action steps specified in the plan.
4. *Review and update:* Review the plan and make adjustments regularly to exercise proper control of this career path. Knowing what it takes to move to the next stage, and preparing oneself in time for that big opportunity ahead, represent a good mantra for Joe Engineer to follow. Benjamin Disraeli said, "One secret of success in life is for a man to be ready for his opportunity when it comes."

Example 2.5

Describe the top-five key lessons/insights you have learned/gained from this chapter, including justifications.

Answer 2.5

The most important capability for future leaders to nurture and cultivate is strategic planning, which requires the creation of a vision for defining future directions. Forecasting technologies, business conditions, marketplace developments, and customers' needs is critical but difficult to determine, as choices may have to be made based on intuition, judgment, and hunches, rather than hard data. Future leaders need to nurture strategic planning skills through keen observations, deep reflections, and trial and error. Operational planning is more or less straightforward; it is essential for implementation, which includes 85% of efforts required in order to achieve success in any endeavor. Planning activities are essential to both corporate and personal life. Policies and procedures are mostly administrative in nature; however, they need to be taken care of even though they are not particularly exciting or rewarding.

2.9 Conclusion

Both strategic and operational planning are important, because the success of a company depends on creating new paths to the future as well as on implementing short-term operational plans to secure profitability at the present time.

Engineering managers are expected to involve themselves in both strategic planning and operational planning. Both types of planning require forecasting and action planning. To regulate work, managers may also participate in issuing policies and establishing procedures. Among these planning activities, forecasting and strategic planning are difficult, as they involve making estimations of the future. The remaining planning activities related to policies and procedures are administrative or operational in nature. These activities are rather straightforward and should appear to be relatively easy to understand and implement. Doing extremely well in these administrative tasks will not necessarily make a manager outstanding, but not doing well in them will project a negative image of the engineering manager.

To demonstrate managerial leadership, engineering managers need also to be proficient in technology forecasting. Technology forecasting involves the critical evaluation and adaptation of emerging technologies so that the company's products and services offered to the marketplace become better, cheaper, and faster to deliver. A primary opportunity for engineering managers to add value is to participate actively in creating technology projects affecting the company's future in major ways.

QUESTIONS

1. On the eve of leaving her alma mater, Stacy Engineer remembers the encouraging words of the commencement speaker: "Graduation is the happy beginning of an exciting life ahead." She is, of course, excited about her new master of engineering degree that she received with honor. But she is also a bit concerned about what to do now to make her new life exciting and filled with happiness. Apparently, what she needs is a road map into the future. How can you help her?
2. The company has always been focused on the high-quality and high-price end of the market. Now, market intelligence indicates that some competitors are planning to enter the low-price and low-quality end of the market. What should the company do?
3. Mission and value statements are indicative of the direction in which a company is headed. What are typically included in the statements of mission and values of well-known companies in the United States? Please comment.
4. What are included in the typical operational guidelines some industrial companies have developed? Please comment.
5. There are always risks (risks of failure) associated with the experimentation of a new manufacturing process or with entry into a new global market. How should one decide to proceed or not to proceed with a risky venture? What is the proper level of risk for a company to take?
6. The marketing director needs to submit a strategic plan for entering a new market. She knows she needs long periods of uninterrupted time. She considers two options: (1) staying at home to do the plan or (2) delegating some parts of the plan to her subordinates. What are the factors the director needs to consider when she chooses the best way to come up with this plan?
7. XYZ Company has been a one-product company focused on developing and marketing a package of innovative enterprise resource planning (ERP) software specialized for law firms and operated in computers running on a proprietary operating system software developed by the company. Customers must purchase both the hardware and software as a bundled package from XYZ Company.

The company also provides around-the-clock services to ensure that the combined hardware and software system performs reliably, as lawyers are known to be typically disinterested in troubleshooting computer systems. This product-bundling strategy works out well for the company, and the sales revenue of XYZ increases dramatically during its first three years in business.

However, market intelligence shows that new ERP software products are now being introduced by competitors. These new ERP software products are quite capable of performing all of the data processing functions typically required by law firms. Furthermore, these new ERP software products can run on any computer using its existing operating system, thus eliminating the need for customers to purchase dedicated computers.

The president of XYZ Company recognizes the potential threat imposed by these new ERP software products. He wants to know the best counterstrategy he should plan and implement. Design and explain this counterstrategy.

8. Sandy Smith is about to graduate from the University at Buffalo with a master's degree in engineering and a GPA of about 3.8. She wants to find a good job that allows her to best utilize her strengths and capabilities. Her short-term goal is to become an operations manager in a manufacturing enterprise in 10 years. Modeled after Example 2.4, how should she plan to achieve this specific goal?

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3

Organizing

3.1 Introduction

Organizing is another important function of engineering management. Organizing means arranging and relating work so that it can be done efficiently by the appropriate people (Glushko 2013; Lewis 2014). Corporate efficiency is usually achieved by a proper partition and distribution of work, as well as by a suitable coordination between the interrelated groups of people participating in the work that is subject to time constraints, resource limitations, and business priority.

Managers are empowered to design the organizational structure—the team, group, department, and so on—and to define the working relationships conducive for attaining the company's objectives. Doing so will

- Ensure that important work gets done in priority order
- Provide continuity
- Form the basis for wage and salary administration
- Aid delegation
- Facilitate communication
- Promote growth and diversification
- Encourage teamwork by minimizing personality conflicts and other problems
- Stimulate creativity

It is generally true that dedicated people can make any organization work. However, dedicated people in well-organized units can get outstanding work done. Bernard Russell said, "Too little liberty brings stagnation and too much brings chaos."

This chapter compares several basic forms of organizational structures commonly employed in industry. Special emphasis is placed on teams composed of cross-functional members. Illustrative examples are included for specific organizational structures, which are used to enhance innovation, resolve conflicts at the interface between design and manufacturing, promote collaboration at the interface between research and development (R&D) and marketing, and foster employee motivation. The critical managerial tasks of assigning responsibilities while maintaining control and establishing work relationships are also discussed.

3.2 Definitions

Before reviewing the managerial function of organizing, it is useful to introduce a few definitions.

1. *Span of control*: The span of control refers to the number of people supervised by a manager or supervisor. It may be small (a few people) or large (20 or 30 people). The choice of a small or large span of control depends on workforce diversity, task volume, and complexity of work, as well as on the geographic dispersion of workers. Large span leads to lower costs and greater organizational efficiency, but it also leads to a lower intensity of supervision. The current trend is moving toward larger span of control, increasing from 7 to 20 or more, due to
   a. Reduction of middle management levels
   b. Enhanced communication tools
   c. Empowered knowledge workers, allowing decision-making at lower levels by people with more applicable knowledge
   d. Improved morale, productivity, and profitability, made possible by less detailed supervision, particularly over professional workers
2. *Organization types*: The *line organization* (e.g., a profit center) performs activities directly related to the company's main goals. Examples include business management, product management, sales and marketing, product design, and engineering, production, and customer services.

   On the other hand, the *staff organization* (e.g., a cost center) provides advice and comments in support of the line organization's work. Examples include research and development, financial and accounting, information services, procurement, legal affairs, public relations, and facility engineering.
3. *Overlap and duplication of responsibility*: This refers to a situation where two or more people do the same work and make the same decisions. Such undesirable situations are to be avoided in any organization, as they represent sources of conflicts and wastes.
4. *Specialization*: Specialization refers to the increased degree of skill concentration in narrow technical domains. Specialization of work leads to improved efficiency. However, overspecialization may cause monotony, fatigue, disinterest, and inefficiency on the part of the worker.
5. *Work arrangement*: Work needs to be arranged in a rational and logical manner. The logical arrangement of work promotes task accomplishments and enhances personal satisfaction for more workers over a longer period of time.
6. *Additional selected management terms*: *Authority* refers to the legal or rightful power of a person, by assignment or by being associated with a position, to command, act, or make decisions—this is the binding force of an organization. *Responsibility* is the duty to perform work assumed by a position holder in an efficient and professional manner. *Accountability* represents an upward-directed obligation to secure the desired results of the assigned work.

Other terminologies related to organizing may be found in Fineman et al. (2005).

3.3 Activities of Organizing

As a function of engineering management, organizing consists of several specific activities described next:

1. *Organizing one's own workplace for productivity*: The organization of one's own office, file systems, and daily routine, so that work can be done efficiently (Online Business Buddy 2013).
2. *Developing organizational structure*: The identification and assortment of work so that it can be done efficiently by qualified people in teams, task forces, committees, departments, and other suitable arrangements (Galbraith 2014, Burton et al. 2011).
3. *Delegating*: The entrustment of responsibility and authority to others and the creation of accountability for results. Managers must learn to delegate effectively in order to achieve results by working through people; to distribute the workload while maintaining control to make the best use of available talent in the organization (Harvard Business Review 2014).
4. *Establishing working relationships*: The creation of conditions necessary for the mutually cooperative efforts of people. Managers must make commitments, set priorities, and provide needed resources (money, time, physical facilities, skills, and know-how) to foster teamwork and collaboration among people (Goold 2014; Harvard Business Review 2013).

All of these organizing activities exist for the purpose of achieving improved efficiency in performing work.

3.4 Organizing One's Own Workplace for Productivity

How well is the office of a typical engineering manager organized? A simple test is to ask how much time it would take for the engineering manager to find a phone number, a piece of paper, or a file when his or her superior calls. Surveys indicate that an average executive spends about five weeks per year looking for lost items (Zeigler 2010).

Engineering managers need to be organized with respect to time, paper, and space. A basic guideline recommended by efficiency experts is as follows: "The less you have, the less you have to sort through." A few rules of thumb that are recommended for the engineering managers to become more efficient are as follows:

1. Use an online calendar that indicates time slots blocked out for important tasks. Such a calendar allows others—one's own secretary and peer managers—to schedule meetings conveniently. One should also prepare agendas before holding or attending meetings.
2. Maintain a "to-do" list. Set priority to tasks and separate urgent tasks from others by assigning most urgent tasks to list A, moderately urgent tasks to list B, and least urgent tasks to list C. Consult the lists regularly. If one is computer literate, then use electronic systems.

3. File papers based on "access," or use a logical keyword system under which to find the document later. The file system may be based on categories such as projects, persons, or deadlines. Keep a master copy of the file index nearby and update it often. This master index helps locate a file and safeguards against creating duplicate files. A document should be kept if
   a. The information it contains cannot be easily found elsewhere. (How difficult would it be to obtain or reproduce it again?)
   b. The information it contains helps the engineering manager to reach a goal. (Does this piece of paper require action?)
   c. It has been consolidated as much as possible.
   d. It is up to date. (Is it recent enough to be useful?)
   e. It is really necessary to keep this document. (What is the worst thing that could happen if this document is unavailable?)

   Most professional workers are said to use only about 20% of the paperwork they keep. The challenge is, of course, to decide which 80% can be thrown away. Question every piece of paper that crosses the desk. Use the wastebaskets frequently. Reserve a time slot during each day (e.g., after work, but before departing for home) to sort, file, and toss unneeded files. Make use of travel time (at the airport, on the plane, and in the hotel) to organize one's own files.
4. Implement a system for keeping track of names and phone numbers (e.g., Rolodex for business cards, address book, Palm Pilots, and smartphones).
5. Cultivate the use of the phone. Prepare notes before placing calls and make the calls brief (e.g., by standing up).

With practice, every engineering manager can get his or her workspace and daily routine organized for productivity.

Example 3.1

David Pope, engineering director, started out the day uptight. His young child had the flu the night before, and he had been up all night to help. Upon arrival at his office, David had to make urgent phone calls to approve a two-week overtime work plan due to a plant fire the night before and to plan for a product committee meeting the next day to counter environmental concerns about a wastewater treatment plant.

Then he spent 30 minutes reviewing the qualifications of new candidates and decided on one. He asked for salary information and wanted to examine the offer before it was sent. He asked for further justification for the budget requested by industrial engineering for a minicomputer. Without reading it, he approved the research proposal from material engineering. He rejected an invitation to speak at a regional meeting of the American Society of Plant Engineering by giving an untrue reason.

David made a note for a United Way board meeting coming up soon. At 10:00 a.m., he met with two consultants for 1 hour and 45 minutes on a formal wage and salary plan and then directed his administrative assistant to work out the details. He promised to inform all department heads and asked for cooperation.

As he walked back to his office after lunch, David noticed several engineers were still playing bridge after 1:30 p.m., and he planned to remind their department heads of this truancy from work.

As soon as he walked into his office after lunch, George Wallace, the general sales manager, called to complain about inadequate responses from engineering to field sales requests. David promised to look into it after receiving specific details. In return, he asked for Wallace's support at the product committee meeting the next day.

David gave a retirement plaque to Glen Sanford in his own office in the presence of the personnel director at 1:45 p.m. Furthermore, he approved the request of two engineers for a week of overtime to design a new, final quality control station.

At 2:00 p.m., he was asked to attend a three-hour budget meeting at 3:00 p.m. called by the president. In the meeting, guidelines and a timetable for next year's budget requests were discussed. For engineering, he was told there would be an increase of only 10%. He then arranged for a meeting with the president and the controller at 2:00 p.m. the next day to request more money.

As he was about to leave for the day around 6:30 p.m., his wife called to say that his child is doing all right, but he has to go to the party of the executive vice president alone.

What do you see are David Pope's problems? How do you suggest improving his day?

Answer 3.1 (Adopted and modified from Shannon 2009.)

David Pope had four major problems: (1) poor time management, resulting in the day being spent responding mostly to others; (2) lack of delegation; (3) inadequate utilization of administrative assistant; and (4) deficient guidelines for handling minor projects. David Pope could improve his day as follows

1. Review the day's schedule in the morning and call in the administrative assistant to
    a. Get background information on wage and salary plan for the 10:00 a.m. meeting with the two consultants. Prevent this initial meeting from dragging out to 1 hour and 45 minutes.
    b. Request the personnel director to invite peers of Glen Sanford to attend the plaque-awarding ceremony in his own office.
    c. Collect information on the budget request for the minicomputer from industrial engineering.
2. Return all phone calls.
    a. Authorize the two-week overtime work plan due to plant fires.
    b. Send Jamieson (who wrote the report) to the product committee meeting to defend the wastewater treatment plant.
    c. Approve Oscar Ford to use two engineers for one week to design a new, final quality control station. Ask the administrative assistant to draft new guidelines for manpower allocation in minor projects.
3. Upon receiving notice for the 3:00 p.m. meeting called by the president, get the administrative assistant to start preparing the engineering positions on budget. Review these positions at 2:00 p.m. Call an urgent meeting for 2:15 p.m. with department heads to finalize the engineering position.
4. Present a plaque to Glen Sanford before many of his peers, express appreciation for his services, and wish him well.
5. Become well prepared to attend the 3:00 p.m. meeting. If more discussions are needed, request a follow-up meeting with the president. If additional budget preparations are required the next morning, leave a note to the administrative assistant.
6. Go to the party alone, and be happy.

3.5 Developing Organizational Structure

The purpose of developing organizational structure is to help ensure that important work related to the key objectives of the unit or department is performed. By developing the right organizational structure for pursuing specific work, managers hope to eliminate or minimize the overlap and the duplication of responsibilities. Also, by logically grouping work according to positions in the organizational structure, managers will be in a better position to utilize available talents, encourage mutual support among workers, provide technological foci, and facilitate problem solving. Doing so will ensure that management, technical, and operating work are distinguishable so that people can be most efficient in performing such work (Kumar 2012; Burke 2013; Daft 2012).

Many industrial organizations adopt one or more of the following structures.

3.5.1 Functional Organization

The functional structure is a very widely used organizational form in industry. Companies that favor this organizational design include (1) manufacturing operations, process industries and other organizations with limited product diversity or high relative stability of workflow; (2) start-up companies; (3) companies with narrow product range, simple marketing pattern, and few production sites; and (4) companies following the lead of their competitors.

Companies that prefer the functional structure establish specific departments responsible for manufacturing, finance, marketing, sales, engineering, design, operation, procurement, and other such functions (see Figure 3.1).

The functional structure has certain advantages, as it (1) permits a hierarchy of skills to be developed and maintained, (2) facilitates specialization in order to achieve high levels of excellence, (3) simplifies coordination as experts in various functional areas are logically grouped together, and (4) allows the use of current technologies and state-of-the-art equipment.

On the other hand, it also has some disadvantages, such as (1) encouraging excessive centralization, (2) delaying decision-making due to barriers created by the departmental boundaries, (3) compounding communication line loss, (4) restricting the development of managerial skills of employees, and (5) limiting employee growth because of constrained exposure to professional experience outside of the departments.

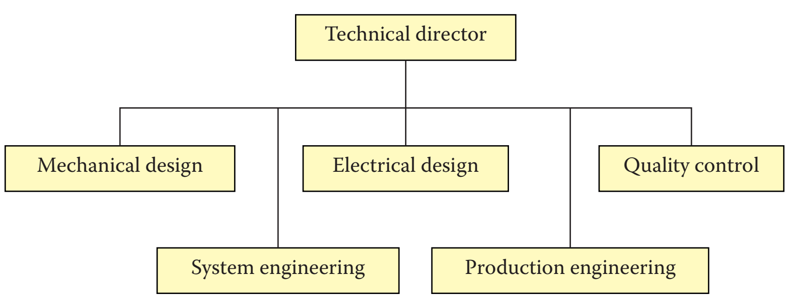

FIGURE 3.1
Functional organization.

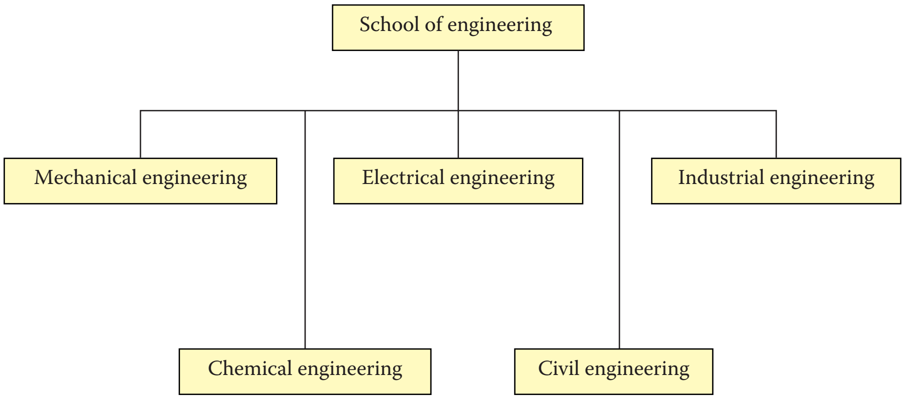

FIGURE 3.2
Discipline-based organization.

3.5.2 Discipline-Based Organization

Universities, governmental laboratories, and some contract research firms are organized according to disciplines. These organizations contain departments for mechanical engineering, physics, business administration, and other specific disciplines so that specialists may focus on these disciplines in order to excel in research and other activities they pursue (see Figure 3.2).

3.5.3 Product/Region-Based Organization

Large companies may produce and market products/services of various types to different customers in geographically dispersed locations. More often than not, each of these products/services may require different production, sales, and business strategies to achieve success in the marketplace. Thus, some companies elect to organize themselves into a product-based structure (see Figure 3.3). If the company is marketing products/services in various geographical regions, each demanding location-specific strategies to penetrate the local markets, and each applying different customer customization strategies according to local needs, a region-based structure may be preferred (see Figure 3.4). In either of these cases, a product/service or regional manager could head up the activities with the overall profit and loss (P/L) responsibility for the product/service or region involved. This

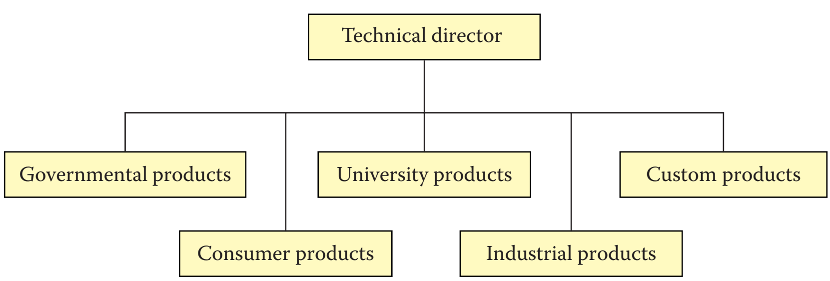

FIGURE 3.3
Product/service organization.

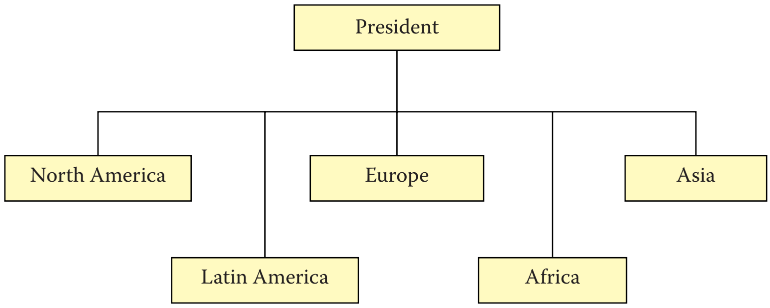

FIGURE 3.4
Region-based organization.

manager is further supported by the relevant experts in production, marketing, and other required functional areas.

This type of product- or region-based organization enjoys the following advantages: it (1) focuses on end products/service or geographical regions for improved local adaptation, (2) facilitates companywide coordination, (3) encourages management development of employees, (4) provides for decentralization, and (5) opens ways for unlimited growth.

The disadvantages for such organizational structure are the following: (1) costs may be high due to layers and autonomous or duplicated facilities, (2) it may require added management talents, (3) specialists may easily become obsolete due to a lack of focus and dedication, and (4) changes are slow to implement because of the complex organizational bureaucracy.

The organizational structure types just described have one thing in common: they all have a hierarchical structure with a clearly defined chain of command, a structure originated from the military.

3.5.4 Matrix Organization

Some companies utilize the matrix organizational structure as a short-term arrangement for specific projects and tasks involving both functional group employees and project managers (Metcalfe 2014; Hall 2013; Finerty and Kraemer 2012).

Managers of functional groups supervise technical contributors who have valuable skills and know-how. Project managers are those entrusted by upper management with the responsibilities of managing specific projects, such as capital projects, the design of new products to specifications, and the creation of business entry strategies. Project managers have resources—money, time, facilities, and management support—and they "borrow" employees from the functional groups to accomplish the work (see Figure 3.5). When functional group employees complete their work for a given project, they usually return to their respective home groups to continue their original home-based assignments.

The advantages of matrix organizations are that project managers focus on schedule and cost, whereas functional managers concentrate on work quality and expertise. This arrangement offers a balance of workload, and it is excellent for participating employees to achieve wide exposure within the company by interacting with those outside of their special domains of expertise.

The main disadvantage is that this structure requires participating employees to report to two bosses (dual reporting), thus violating the "unity command" principle. When employees are assigned to work on several projects, they may be subjected to marching

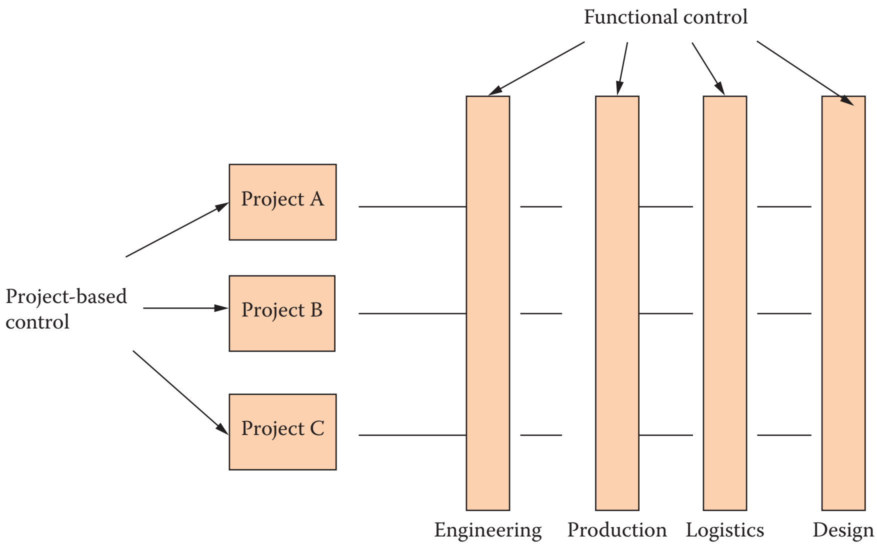

FIGURE 3.5
Matrix organization.

orders issued by several superiors. In practice, conflicts between the functional and project managers are frequent and severe, mostly with respect to task priority, manpower assignment, interests, quality versus urgency, performance appraisal, employee promotion, and other issues.

Matrix organization demands a delicate balance of power between functional and project managers. Functional managers control manpower, particularly who works on what projects, when, and for how long, in addition to controlling knowledge and facilities. On the other hand, project managers have an approved spending budget and the support of upper management. A lack of a balance of power will occur when the functional managers have their own funds to support their own people, thus making them less dependent on project managers. An unbalance of power will also occur when project managers outsource some of the needed work that is not delivered by the functional managers. Under these circumstances, the matrix organization might break down.

Because of the aforementioned built-in conflicts, many companies in industry are moving away from the matrix organizations in favor of teams.

Example 3.2

Once the functional manager and project manager agree on a project schedule, who is responsible for getting the work performed? Who is accountable for getting the work performed? Why the difference, if any?

Answer 3.2

Responsibility and accountability are two different management concepts.

In a matrix organization, the project manager delegates tasks to the functional manager, who in turn assigns specific tasks to individual employees in his or her functional group. The functional manager remains responsible for getting the work performed, whereas the project manager is accountable for the results of the work that has been delegated to and done by the functional manager (or his or her people).

The project manager is accountable for achieving specific project objectives. He or she defines the pertinent tasks to be accomplished. If the tasks are defined improperly, causing the project objectives to be impossible to attain, the project managers are accountable for such mistakes. The functional manager, on the other hand, is responsible only for supplying the right people with the proper skills and dedication to accomplish the stated tasks. The functional manager is responsible for accomplishing the agreed-upon tasks in an efficient and professional manner.

3.5.5 Team Organization

A team is composed of members who are "on loan" from their respective functional departments and are thus assigned to work full time for the team leader in tackling high-priority, short-duration tasks or projects (McCloud 2014; Nir 2013; Harvard Business Review 2011). Since all team members report to the team leaders only, conflicts arising from dual reporting are eliminated (see Figure 3.6). Examples of team organization include product development teams and special task forces.

3.5.6 Network Organization

In response to rapid changes in customers' needs, advancements in technology, marketplace competition, and globalization, some companies have started pursuing certain new business paradigms that are based on thinking globally and acting locally (Chen and

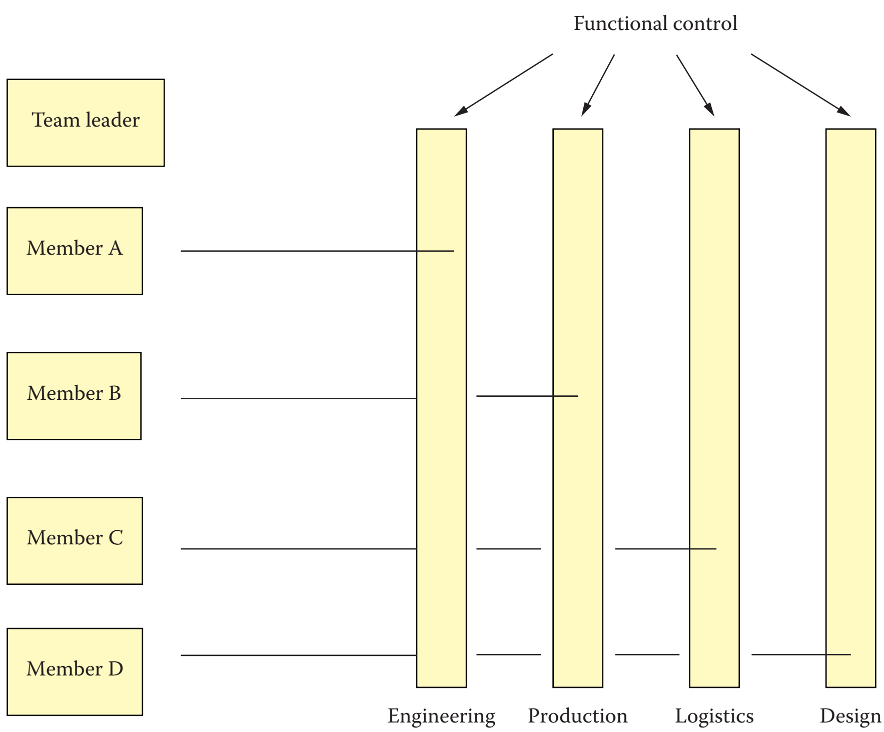

FIGURE 3.6
Team organization.

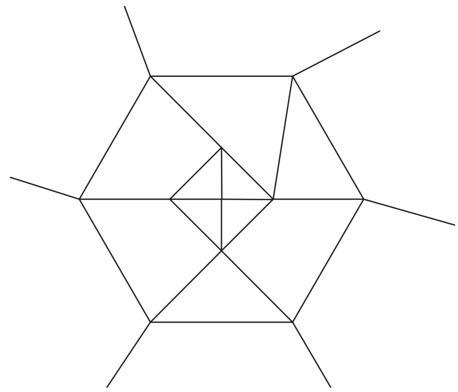

FIGURE 3.7
Network organization.

Wang 2015; Easley and Kleinberg 2010). One such paradigm is the inclusion of local suppliers' inherent technical skills and capabilities as a part of corporate strength.

Companies form alliances, create business networks, and establish supply chains with regional companies to manufacture, assemble, market, deliver, and service products for specific regional markets (see Figure 3.7). At the nodes of such networks are knowledge workers who manage relationships with others (e.g., suppliers, customers, functional groups within an organization, and other such partners) (Hoffman et al. 2014).

The number of such business network arrangements is expected to grow with time. Once formed, these networks must be properly maintained. Specific parts of these networks may be activated from time to time for business strategy development, product development, system design, quality control, logistics, customer service, and other such important projects (Ramos 2011).

Partners linked by these networks may be of different cultural and business backgrounds with divergent value systems and perspectives, and may be dispersed in different geographical regions. Engineering managers serving on such intercompany network organizations may also be challenged by the expected resistance to change, difference in working habits, absence of motivation and control means, and slowness in consensus-building and decision-making.

Network organizations behave a step closer to organizations in chaos. According to *complexity theory* (sometimes also called *chaos theory*), these organizations exhibit several unique features (Holland 2014; Pflaeging 2014).

1. All members are independent, flexible, and empowered. They behave responsibly, free of the traditional top-down command-and-control structures.
2. Members tend to self-organize themselves by ways of intensive interactions between the members and to form self-directed network organizations.
3. The flexible organizational form fosters creativity and innovation of empowered members.

The complexity theory claims that organizations composed of members with personal autonomy will be better able to operate in economical, political, and social-cultural environments that are turbulent and rapidly varying (Alvira 2014). Rigid objectives and instructions will no longer be effective in managing such enterprises in the emerging global economy. The following three underlying principles have been proposed to describe such organizations:

1. *Connectivity*: Members in the network organizations recognize themselves as an integral part of the whole organization and believe that their best interests are served when the interests of the greater whole are served. Members are closely connected with one another.
2. *Indeterminacy*: The turbulent future cannot be readily predicted or planned. Members of the organization need to empower themselves to act with confidence, courage, and integrity.
3. *Consciousness*: Organizations are products of the collective thinking comprising them. The collective consciousness of the organization is defined by all of its members. Everyone is a vital contributor.

Members exercise self-control and are guided by shared essential values, such as honesty, loyalty, integrity, independence, and responsibility. Teamwork is a hallmark of such organizations, wherein individuals are increasingly autonomous, flexible, and dedicated. Product customization is a likely means for such organizations to achieve success in the marketplace.

Network organizations involving independent supply partners could be difficult to manage. It is not likely that much can be accomplished by leaving them alone to direct themselves, as suggested by the complexity theory. Engineering managers need to prepare themselves to effectively lead such network organizations.

Example 3.3

Company X manufactures automobile jacks, hubcaps, and a variety of fittings. These products are sold as replacement parts through auto supply chain stores. The business of the company is growing, with production facilities located in rented buildings over various parts of the city. The production staff is expanding constantly. Now the president of the company wants to expand into the brass-fittings business. However, the president realizes that, after this newest expansion is accomplished, the company should consolidate to make its production operations more efficient.

Which organizational structure should the company adopt now, so that it can best accommodate its current needs of business expansion and also lay the foundation for anticipated consolidation thereafter? What information is needed to set forth such an organizational structure? What are the crucial variables that should be considered in the design of such an organization?

Answer 3.3

To expand the brass-fittings business, Company X should set up a multidisciplinary team initially. This team will be empowered to come up with a business plan to enter the brass-fittings business on the basis of market research and competitive analysis. The plan should include market share position, time-to-market goals, marketing strategies, capital investment, and production or sourcing requirements. It may be useful to retain competent external business consultants for advisement.

The business plan defines the needs of personnel (capabilities, experience, and number), facilities, and other resources required for implementation. A product-centered department is set up to be responsible for the profit and loss of the brass-fittings business. While the distribution of brass fittings may be readily handled by the existing organization in the company, special attention needs to be paid to production, marketing, engineering, and service of brass fittings.

Once the brass-fittings business is fully established, the production facilities of brass fittings could be integrated into the production organization of other company products in order to realize scale of economies advantages.

The organizational design must be flexible to effectively serve the purpose at hand. Crucial variables to be considered in the organizational design include the significance of the brass-fittings business to the company's overall performance (e.g., market size, competition, and profitability), extent of the resources required of the company to enter the brass-fittings business, and the management and technical talents available inside and outside of the company.

3.6 Enhancing Corporate Performance by Organizing: Examples

Organizing is an efficacious method to achieve the critically important objective of doing things right (or performing tasks in the most efficient ways). Management can put the right people together and keep the wrong people separated so that work efficiency and goal attainment can be greatly enhanced (Lawler 2001). The following are several best-practice examples of how company productivity was raised by employing organizing strategies.

3.6.1 Organizing for Profitability: Service Profit Chain Model

For every service company there are five stakeholders, namely, customers, employees, suppliers, investors, and the community in which the company operates. Not all of them are equally important from the company's standpoint. In the new economy of services, front-line workers and customers need to be the center of management's concern. Customers are value oriented, emphasizing results in relation to costs. As profits come from customers, the key concept of the service profit chain model is to treat employees well so that they make customers happy, who in turn buy more, which leads to improved corporate profitability, and allows suppliers and investors to be paid properly, as well as avoiding upsetting the communities in which they operate (Heskett et al. 2008). Figure 3.8 illustrates this model.

In Figure 3.8, organizational strategies refer to preparatory activities and tasks related to workplace design, job design, employee selection and development, employee rewards and recognition, and the introduction of applicable tools for serving customers. Specifically, companies strive to take the following steps:

1. Hire employees with the right attitude toward jobs, coworkers and companies, as people are the heart of service businesses.
2. Promote capabilities (tools, technology, and infrastructure) and empower service workers to achieve results for customers.
3. Communicate with customers and employees to get feedback and recognize good performance.
4. Achieve employee satisfaction as related to jobs, training, pay, advancement fairness, treat people with dignity, teamwork, company's interest in employees' well-being. Set up an 800 phone number to help solve employees' problems.
5. Link manager's compensation (say 20%) to customer satisfaction.

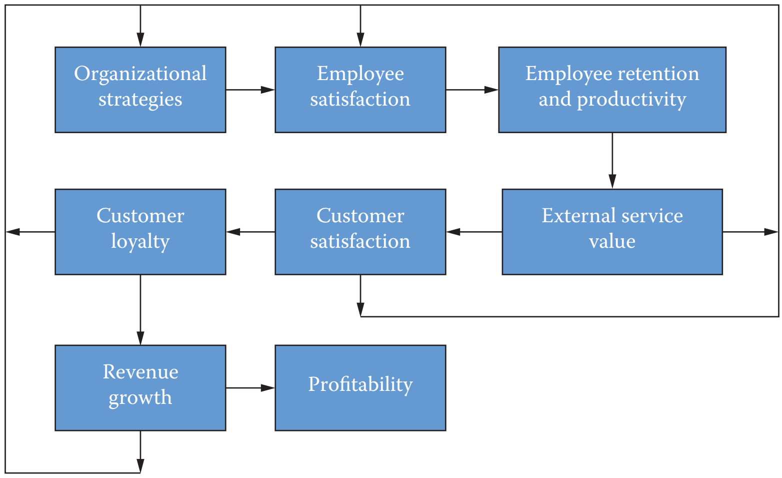

FIGURE 3.8
Service profit chain model.

Customer satisfaction is the ultimate goal that all service companies want to achieve. Customer satisfaction can be measured by a set of metrics using third-party interviews. These metrics include: (1) percentage of loyal customers with repeat businesses; (2) percentage of sales due to repeat customers; (3) funds spent to promote customer retention; and (4) company's understanding of the reasons for customer defect, and actions taken to mitigate. Service quality is a function of the gap between perceptions of active service received and customer's expectations beforehand (as related to reliability, timeliness, empathy and authority of service delivery, extent of evidence for service rendered). It is of critical importance to the company that service errors be quickly corrected. External service value refers to the value received by customers based on the extent in which the service designed and delivered satisfies their needs.

Customer loyalty results in retention, repeat business, and referrals. For service companies, the service profit chain model represents a useful organizational design concept because it emphasizes, among other stakeholders, the two most important ones: employees and customers.

3.6.2 Organizing for High Performance by Using Flexible Structure

Organizational structures are known to have an impact on corporate performance. Some companies allow the structure to continuously evolve in order to adapt to changing opportunities in the marketplace.

According to Morgan (2014) new-style companies achieved great business success by being relentlessly committed and by exercising discipline from the top, as well as practicing three organizational principles:

1. Make it everyone's job to identify new opportunities. Company culture must support such practices by way of feedback loop and financial incentives.
2. Decide quickly on project priority. Speed and coordination are critically important in implementation. Use technology to support decision-making wherever possible, and fill the gaps with fast, centralized, senior-level decision-making.

3. Hire people for specific roles such as marketing and technology support. This is needed for implementing ideas to quickly capitalize on new opportunities in the marketplace.

3.6.3 Organizing for Innovation

Some companies are more focused than others on developing and sustaining corporate competitiveness by nurturing innovation. Innovation can be fostered by company structure.

Judging from the degree of innovative novelty, Chesbrough and Teece (2002) suggest that there are two types of innovations: autonomous and systemic inventions. *Autonomous inventions* are those which can be pursued independently of other innovations. For example, inventions related to turbochargers could be pursued independently of inventions related to automobiles, to which turbochargers are applied for boosting power output. Similar relationships exist between filters and air conditioners, motors and compressors, and color-print films and analog cameras. *Systemic inventions*, on the other hand, are those that must be developed in close coordination with others. Examples include the development of product design, supplier management and information technology for lean manufacturing, and films and cameras for instant photography. Because autonomous inventions may be pursued independently of other inventions, they are better suited for virtual organizations. Vertical organizations, on the other hand, are more likely to succeed in pursuing systemic inventions that require close coordination and intensive information sharing.

Organizing a company's structure to be virtual means that all noncore functions are typically outsourced. These virtual companies form supply chain partnerships and business alliances to develop, manufacture, market, distribute, and support their offerings. They use incentives—sign-up bonuses, stock options—to attract highly trained independent inventors to generate breakthrough inventions. Because of the self-interests of all participants, the coordination between these partners can be difficult, rendering the resulting inventions of value only to some, but not to others.

Vertically organized companies are those that have rigid hierarchical organizational structures. They maintain control of all functions and typically have well-established procedures for settling conflicts and for planning all activities that promote innovations. Systemic inventions require information sharing and adjustments, which these vertically integrated companies can readily promote and safeguard. However, they cannot offer the high incentives that virtual companies use to attract independent inventors. As a consequence, they may not be able to access top-level talent for creating innovations.

Therefore, when organizing for innovations, one must choose between talents and control. The key is to select the right kind of organizational form to match the type of innovation (autonomous, systemic, or a mix of the two) the company needs. At one extreme, virtual companies are suitable for pursuing autonomous innovations. At the other extreme, vertical companies are excellent for pursuing systemic inventions. As the invention type changes gradually from purely autonomous to purely systemic, the company should consider intermediate forms of organizations such as alliances, joint ventures, and collaborations with autonomous divisions.

Looking from the perspective of value-added applications, Keeley et al. (2013) suggest that there are in fact 10 types of innovation related to the following categories

1. Business model (the strategy to generate profitability via pricing, marketing and/or customer service initiatives)

2. Network (including supply chain partners and open innovation collaborators)
3. Structure (organizational design, virtual teams, and joint ventures)
4. Process (work processes related to design, production, and customer support)
5. Products/services design (novel features, unique functionalities, and emerging technologies)
6. Products/service systems (value-added capabilities to form ecosystems)
7. Customer support services (web design, information access, and problem solving)
8. Channel (advertising to reach customers, delivery of products/services)
9. Brand (creation and maintenance of brand reputation)
10. Customer engagement (customer interactions and relationship management)

Innovations in all the above-cited categories are valuable, as some will create strategic differentiation (e.g., categories 1, 5, 6, and 9) and others enhance operational excellence of the enterprise. Thus, innovations in categories 5 and 6 are more likely to be of the breakthrough types, whereas the rest are of the incremental types.

Gibson (2016) described the following four lenses as a new powerful tool for promoting critical thinking:

1. Identify unmet needs overlooked by others. Thomas Edison said, "None of my invention came as accident. I see a worthwhile need to be met and I make trial after trial until it comes."
2. Apply resources synergistically to define solutions.
3. Ask what-if questions in order to remove constraints imposed by conventional thinking pattern. Albert Einstein said: "To raise new questions, new possibilities, to regard old questions from a new angle, requires creative new imagination and marks real advance."
4. Gather energy to create breakthrough.

For creating innovations in these application categories, teams that are composed of qualified professionals with knowledge and work experience are the preferred organizational type. Enterprises will be best served by pursuing combination innovations in a number of the aforementioned application categories in order to prevent their innovations from being readily copied by their competitors.

Nowadays, few companies can afford to develop all needed technologies internally. A mix of approaches is usually adopted. Some technologies are developed in-house to serve as the core part of the value chain. Other less critical ones are typically purchased outright or acquired through license, partnership, and alliance. Over the long run, however, key value-added advances will need to come from within.

3.6.4 Organizing for Performance at Design–Manufacturing Interface

Conflicts are known to exist at the interface between product design and manufacturing. These conflicts cause frequent cost overruns and product introduction delays. In many traditional companies, the product design group signs off on the design, and then they "throw it over the wall." The group responsible for manufacturability takes over and reexamines the design for cost-effective mass production. While product design may have focused on performance and aesthetics, manufacturing looks after production efficiency. Also contributing to these conflicts are other factors such as (1) funding periods for design and manufacturing that do not overlap, (2) differences in education between design and manufacturing staff, and (3) offices that are not at the same location.

Some of these difficulties may be removed by way of organizing (Anderson 2014). Organizational options for improving the design–manufacturing interface include the following (Dean and Susman 1989):

1. Institute a manufacturing sign-off. Manufacturing has veto power over the final product design. Selected software programs are available to calculate a producibility score for checking on manufacturability.
2. Appoint an integrator who performs liaison work between design and manufacturing and offers a balanced view.
3. Form a cross-functional team composed of members of design and manufacturing, with the final authority resting with the engineering department. The use of such cross-functional teams is known to have significant benefits such as ensuring compatibility between the design and manufacturing processes, saving time, simplifying the design process, and reducing design changes.
4. Combine the manufacturing process and product design into one department.

In general, if the company's culture is conducive to absorbing organizational changes, then the organizational options of the team or combined department are to be preferred. On the other hand, if the products and manufacturing processes are fixed, then the organizational options of the sign-off or integrator tend to make more sense.

3.6.5 Organizing for Heightened Employee Motivation

As a rule, teams are temporary in nature because they are built for specific objectives and will be disbanded after their specific projects have been completed (Wheelan 2014). Only in exceptional cases will teams be exhaustively utilized on a permanent basis to achieve business success. This is the case of AES Corporation.

Located in Arlington, Virginia, AES Corporation is the largest global power company, with sales at $17.146 billion (2014), it operated 90 plants in 18 countries. Seventy-five percent of its business was in contract generation. Table 3.1 shows its income statements for the period 2012–2014.

The company has very few organizational layers and, except for a corporate accounting department, keeps no staff for functional specialties. It is organized into 11 regions, each

TABLE 3.1

Income Statement of AES Corporation

	2014	2013	2012
Revenue (B)	17.146	25.891	17.164
Cost of sales	14.058	12.644	13.581
Operating margin	3.088	3.247	3.583
General and administrative expenses	(187)	($220)	(274)
Interest expenses	365	275	348
Net income	1147	551	(357)

headed up by a manager. Each region is further organized into 5–20 teams, and each team has 5–20 members. Teams are created primarily for the combined functions of plant operation and maintenance.

Each team has no more than one of each kind of expert or specialist. As a result, everyone on the team becomes a well-rounded generalist. In-house qualification exams are held to ensure minimum expertise before job rotation requests of employees are approved. Each team owns what it does and is empowered to make decisions with commensurate authority to implement their decisions. The roles for company leaders are limited to advisors, guardians of the company principles, encouragers, and officers accountable to the outside world.

Employees are compensated according to the following formula: (1) 50% on financial performance and safety and environmental impact and (2) 50% on how well employees follow the four company values—fairness, integrity, social responsibility, and fun. The hiring practice of the company focuses on cultural fit first and technical skills second.

Company representatives attribute their business success for organizing the company in teams to the heightened level of employee motivation made possible by the team empowerment practice.

It should be noted that the AES Corporation example may indeed apply well to other low-tech operations such as warehouses, distribution centers, supermarkets, hardware stores, and service centers wherein repeat common practices are the norm. Everything you would ever want to know about operating and maintaining a conventional power plant has already been sufficiently preserved in manuals; in-depth technical expertise and innovation are not required.

3.6.6 Organizing for Research & Development and Marketing Interface

Some companies in industry are high tech, and others are not. "High tech" refers to products and services characterized by (1) their strong scientific–technical bases, (2) the possibility of being quickly obsolete because of new technologies, and (3) the capability to develop or revolutionize markets and demands when built on new emerging technologies. Examples of high-tech products include semiconductors, microcomputers, and robotics.

High-tech companies need to pay special attention to the interface between R&D and marketing. To achieve business success, a linkage between R&D and marketing must be established. When marketing high-tech products or services, companies typically follow two basic approaches:

1. *Market driven*: When pursuing the market-driven strategy, companies use marketing to define the needs of customers and ask R&D to provide the required innovations to satisfy such needs. Customer suggestions are typically good sources of new needs. In this case, marketing uses tools such as *concept testing*, *product prototyping*, and *pilot testing* to define the specific product or service features needed by customers. Marketing efforts precede the R&D efforts. The consequence of practicing a market-driven strategy is that there may be a possible delay in breakthrough innovations, preventing the company from a timely use of the opportunities offered in the marketplace.
2. *Innovation driven*: R&D employees take the lead in the innovation-driven approach by first making breakthrough inventions based on *preemptive needs* as perceived by researchers. Then, the researchers consider pursuing the inventions to satisfy the real needs and wants of the customers. In such situations, marketing applies

techniques such as *focus groups* to verify new product concepts and applications. There are risks associated with this approach, as identified customers' needs and wants may not be sufficiently satisfied by the breakthrough inventions at hand.

A lack of coordination between R&D and marketing is known to be the cause of business failures in many companies. Furthermore, any new technology advancement by competition can change the company's market position instantly.

Organizing a workable interface between R&D and marketing is a way of avoiding the potential loss of market opportunities due to invention delay and the lack of compatibility of inventions to the actual market needs. Setting up a team of representatives of R&D and marketing to constantly monitor relevant activities and foster communications should be a good organizing strategy (Ellis 2010).

3.7 Concurrent Engineering Teams

Cross-functional teams have become crucial to business success (Ngayo 2014; Blank 2012). In general, teams are set up to (1) generate recommendations, such as a strategy to enter a specific regional market or solve a specific customer-related problem; (2) make or do things—design products, develop new processes, install new assembly lines; and (3) run things—operate plants. The performance of a team is the sum of the performance by individual members plus the work outputs brought about by the members working together. It is the work output delivered by the members working together (the team synergism) that is responsible for the superiority of the overall team performance over the sum of the performances of the individuals. Teams may fail if they are not led properly (Danner and Coopersmith 2015).

Organizing multifunctional teams is often the preferred choice to address complex coordination issues at interfaces. For example, in a typical functional organization, the development of new products follows a sequential process enumerated here:

1. *Marketing* conducts research to identify the customers' needs and defines product features, such as functionality, reliability, ease of repair, resale value, warranty, and so on.
2. *Design engineering* releases specifications, performs functional design, selects material, obtains vendor and supplier inputs, and conducts engineering analyses to incorporate these features into a product.
3. *Manufacturing engineering* reviews and simplifies the product design for manufacturability and reliability considerations.
4. *Service* organization further changes the design to enhance serviceability.
5. *Production* is finally set up to define manufacturing techniques and to mass-produce the product.

Such sequential processes are known to be inherently ineffective with respect to coordination, information sharing, and decision-making. In a concurrent engineering team, representatives of all of the functional groups just mentioned, plus those from procurement, finance, vendors and suppliers, product testing, and logistics, are included as members.

All aspects related to product development are considered early on and concurrently. The goal is to bring forth an optimum product for the company within the shortest period of time and at the lowest possible cost, while satisfying all constraints and meeting all requirements.

All team members have the full support of their respective departments, functional units, and home bases, so that the specific inputs they make on the team at various stages of product development are always the best possible inputs (Lencioni 2002). The keys to the success of concurrent engineering teams are the following:

1. Management commitment
2. Ongoing communications that use advanced communication tools such as the intranet, e-mails, and electronic data interchange (EDI)
3. Teamwork training for all members

The value of the concurrent engineering team concept is evident from the following statistics:

- Mercury Computer Systems, Inc., Lowell, Massachusetts—concurrent engineering team reduced the time to market of its add-on process boards for VME (Versa Module Eurocard) bus from 125 to 90 days.
- Hewlett-Packard Company, Palo Alto, California—cut the time to market its 54600 Oscilloscope by two-thirds.
- Toyota Motor Corporation, Tokyo, Japan—concurrent engineering decreased its product cost by 61%.

In general, concurrent engineering delivered impressive benefits in the order of magnitude shown in Table 3.2 (Parsaei and Sullivan 2012; Stiepandic et al. 2015).

Engineering managers need to become proficient in leading and participating in concurrent engineering teams. Teams may be formed to address any important corporate task. For teams to add value, team leaders need to pay attention to team discipline, team learning, and factors affecting team effectiveness.

3.7.1 Mutual Trust and Accountability

For a "blow-the-roof-off" performance, a team is often the vehicle of choice. But to excel, the team needs to possess the right characteristics, such as the ability to listen well, respond constructively, support one another, share team values, and have discipline (Scott 2014; Struck 2013).

TABLE 3.2

Benefits Derivable from Concurrent Engineering Teams

Activities	Percentage
Reduction of time for product development	30–70
Shrinking the number of engineering changes	65–95
Decrease of time to market	20–90
Improvement of product quality	200–600

A team is a small number of people (usually between 2 and 25) who are committed to a common purpose, develop mutual trust, possess technical skills that are complementary, and adopt an approach for which they hold themselves mutually accountable.

Team members are said to have developed mutual accountability if and when they have reached the emotional state of "being in the boat together." Without mutual accountability, there can be no team of real value.

3.7.2 Team Learning

One decisive factor that affects a team's responsiveness is its learning capability (Sibley and Ostafichuk 2014; Chantal and Peter 2012). In corporate settings, teams need to learn new technologies (such as three-dimensional computer-aided design [CAD], visualization software, project management tools, videoconferencing, web-based net-meeting tools, and others) or new processes (such as new ways of working and new relationships for collaborative work). How fast a team can learn will affect its overall timely performance in attaining the specific objectives at hand.

A learning team is one that is skilled at creating, acquiring, and transferring knowledge and at modifying its own behavior to reflect new knowledge and insights. The team needs to have systems and procedures in place to do the following:

1. Solve problems systematically
2. Experiment with new approaches
3. Learn from its own experience and past history
4. Learn from other's experience and best practices
5. Disseminate knowledge effectively throughout the team and organization

Edmondson (2012) studied a large number of cardiovascular surgical teams. They believe that team learning may be speeded up if the team leaders possess both technical and managerial skills. Because learning has both technical and organizational aspects—status, communications—the organizational skills of the team leader affect the team learning. Factors affecting team learning include the following:

1. *Team composition*: When selecting team members, team leaders should give preference to members' technical competence—retention of a mix of skills and expertise, ability to work with others, willingness to deal with ambiguous situations (risk takers), and self-confidence in making suggestions and proposing ideas while not inhibited by other members' ranking and corporate status. The most effective learning takes place during the process. Teams with a mix of expertise and experience tend to be able to draw on members' relevant past experience, thus promoting learning.
2. *Team cultures*: Team leaders should build a team culture in which some experimentation is encouraged and failure is acceptable.
3. *Leader's style*: Teams will learn better and faster if, as motivation, the team leaders frame the learning as a challenge for all team members.

Factors that do not affect team learning are said to include (1) educational background, (2) prior experience in applying old technologies, (3) top management commitment, (4) status of the team leader, and (5) reporting and auditing processes.

Example 3.4

Some people feel that working as a team, instead of allowing experts to produce more creative outcomes, actually result in watered-down compromises and bland solutions. They view teamwork as a series of exercises in "sharing ignorance." Do you agree or disagree, and why? What can be done to advance the technical qualities of the team outcomes?

Answer 3.4

The concern about the watered-downed outputs of teams is real. Team members from different backgrounds and expertise may indeed have different opinions, which often force the team members to compromise. It is quite true that sometimes the views of the domain experts on the team are not shared and accepted by others on the team, who do not and will not want to understand. However, a Japanese proverb says, "None of us are as smart as all of us."

One obvious way to ensure the technical quality of the team results is to select people to lead who are technically qualified and able to render technical judgment. Another way is to bring in an impartial outside consultant to comment and advise on the relative technical merits of the options under consideration.

Team consensus is good to have, because it allows the team members to jointly own the team outcome. This ownership represents a strong motivation factor to team members who are then inspired to actively implement the team outcome. A technically superior team outcome adds little value if it is not implemented properly.

3.8 Delegating

After a specific form of organization is established—unit, department, team, division, or regional group—the next step is for the engineering manager to delegate the proper responsibility and authority to the selected leaders and workers, and to establish the upward-directed accountability needed to achieve the defined organizational objectives. Therefore, delegating is for the purpose of improving the engineering manager's overall efficiency by assigning responsibility and authority and by creating accountability (Hollingsworth 2013).

The benefits of delegating are many (Thomas 2015; Syversen 2014). For engineering managers, these benefits include: (1) improving the quality and quantity of work performed, (2) relieving the engineering manager to pursue more important duties or gain more time for management work, (3) making the engineering manager knowledgeable of the employee's capabilities, (4) preparing the employee to step in for the engineering manager when needed and hence enabling the engineering manager to be absent from the job occasionally, (5) distributing the workload effectively, (6) developing leadership qualities, (7) easing the engineering manager's job pressure, and (8) reducing costs through more efficient operating decisions.

Delegating is also beneficial to engineers as technical contributors because it (1) makes the job more satisfying; (2) provides encouragement, incentives, and recognition; (3) develops new skills and knowledge; (4) promotes self-confidence; (5) facilitates teamwork; (6) encourages growth and development; and (7) fosters initiative and competence.

It is important for engineering managers to keep in mind what should and should not be delegated. Problems and activities of the following kinds are to be delegated: (1) those

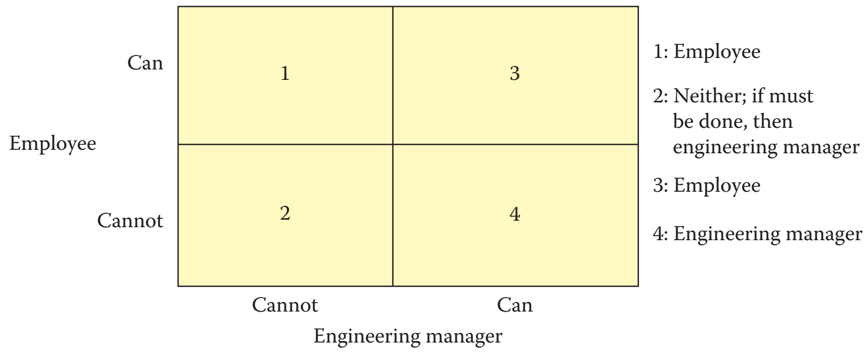

FIGURE 3.9
Delegation matrix.

that require exploration and recommendation for a decision; (2) those that are within the scope and capabilities of employees involved; (3) those that are needed to achieve company objectives; (4) those that promote the employee's development in technologies, business perspectives, and leadership skills; and (5) those that save the engineering manager's time if done properly by the employees.

For delegating, the following guidelines, which are also illustrated in Figure 3.9, may be helpful:

1. What the engineering manager cannot do and the employee can do, the employee does it.
2. What both the engineering manager and employee cannot do, the engineering manager does it.
3. What both the engineering manager and the employee can do, the employee does it.
4. What the engineering manager can do and the employee cannot, the engineering manager does it.

Which problems or activities should the engineering manager not delegate? Such problems or activities include (1) planning/creating plans within larger plans and objectives, (2) resolving morale problems in the group or department, (3) reconciling differences and conflicts, (4) coaching and developing employees, (5) reviewing performance of employees, (6) completing assignments given to engineering managers by their superiors, and (7) completing other assignments only engineering managers themselves should handle (such as confidential committee assignments, "pet" projects, and tasks without proper talented employees to delegate to).

Delegating requires skill and practice. The following are guidelines for efficacious delegation:

1. Explain the importance of the assignment.
2. Check on understanding and confidence.
3. Give the employee leeway in his or her choice of method, unless the procedure has been specified and developed before.
4. Set a goal, timetable, or deadline. A short-term goal is better than a long-term goal.

5. Be reasonable. Keep the goal within the employee's capabilities.
6. Assign responsibilities that go with the job. Allow commensurate authority of decision-making, and let employees accept responsibility for poor as well as good work. (The engineering managers remain accountable for the delegated assignment with respect to their own superiors.)
7. Trust the employee.
8. Give recognition for good work.
9. Share the engineering manager's own worries. Let the employees know your worries about the assignment; explain them openly and fully. Recognize difficulties in the assignment and ask for suggestions on how best to handle the assignment.
10. Make it a project; let the assignment be a challenge.
11. Do not rush in and take over. The employee could use more training if a lack of progress is shown.
12. Do not expect or want perfection.

Certain barriers to delegation do exist. Engineering managers need to beware of these barriers: (1) *Psychological*—engineering managers have fears and worries. If engineering managers let the employee do the work, they may fear their own technological obsolescence, while their employees shine. This fear may be particularly relevant to engineering managers who themselves are technically very strong. (2) *Organizational*—unclear responsibility and relationships, and confused understanding of line versus staff positions may hinder effectual delegation.

There are several more noteworthy observations:

- Delegation tends to be limited by the availability of effective controls. If there is no control, there should be no delegation. Engineering managers should delegate safely only to the extent that one can determine if the work can be correctly carried out and decisions can be made in the manner that they should be. Furthermore, engineering managers should make sure that the plans are sound and that controls are in effect.
- Authority must be commensurate with responsibility. Engineering managers should delegate enough authority to allow decision-making by the employees related to the work.
- Accountability is demanded of employees who are obligated to their superiors for achieving the expected results. Accountability is achieved by properly discharging responsibility and using authority delegated. Effectiveness of and success in delegation depends on the willingness and ability of the employee to perform the work, make decisions, and achieve results.
- Control must be in place. Engineering managers need to introduce midcourse corrections, if needed. Otherwise, delegation will lead to disaster. Setting up performance metrics and constantly monitoring performance will help.

Many engineers fail to achieve success in managerial ranks, partly because they do not know how to delegate properly. Good delegation is a prerequisite for being a good manager.

3.9 Establishing Working Relationships

Another organizing activity to be performed by engineering managers is the establishment of proper working relationships between employees and between units (Parker 2010). This is to ensure that people are working together well enough to achieve the company objectives. Specifically, the activity calls for role clarification and conflict resolution.

3.9.1 Role Clarification

In complex organizational settings, clarifying roles addresses the issues of authority and accountability. For a specific project involving personnel of multiple departments or business units, the need for defining roles of all participants is self-evident. Figure 3.10 illustrates an example of role clarification.

1. General management responsibility
2. Specialized responsibility
3. Must be consulted
4. May be consulted
5. Must be notified
6. May be approved

	Project manager	Project office	Team member	Department manager	Division manager
Prepare bill of materials		3	2	4	5
Visit vendors	6	2	2	5	
Prepare purchase orders		2	4		
Authorize expenditures	1	6	5		
Inspect raw materials		5	3	2	
Quality control testing		6	3	2	
Update inventory files		4	4	2	
Withdraw materials		6	2		

FIGURE 3.10
Roles assignment example.

Companies issue organizational charts that describe the roles and responsibilities of major business units. Employees may assume line roles, coordinating roles, and advisory roles.

1. *Line roles*: Employees with line roles are those in profit centers with monopoly rights within the company to provide products and services to clients and customers. Examples of profit centers include business management, production, and sales. Profit centers are business units empowered to generate profits for the company. Managers of profit centers are accountable for offering quality products and services at competitive prices to ensure that the company makes profits. Profit centers define the services they might need. Managers of profit centers approve the annual budgets of cost centers which provide such needed services.
2. *Coordinating roles*: Employees in some cost centers have monopoly rights for developing and recommending constraints on the position duties of others. These constraints can take the form of approvals, policies, procedures, or planning objectives—legal, financial control, human resources, and so on. They are accountable for achieving higher-level organizational objectives such as consistency in work method, integration regarding external contacts, or cost efficiencies.
3. *Advisory roles*: Employees in other cost centers provide services in support of the profit centers. Examples of such cost centers include R&D, maintenance, investors' relations, financial accounting, and procurement.

3.9.2 Conflict Resolution

In the real-world environment, there are conflicts of many types. Examples of such conflicts may include: (1) technical, including design, analysis, and interpretation of test results; (2) operational, including procedures to perform specific tasks and assign responsibility; (3) emotional, such as treating bruised egos and hurt personal feelings; and (4) political, such as knowing whom to consult and who has a say on specific projects or issues (Coleman et al. 2014).

Engineering managers need to learn how to effectively resolve conflicts (Caspersen 2015; Cloke and Goldsmith 2011). Conflicts may be resolved by (1) *dominance*—dictating a solution, (2) *compromise*—negotiation based on a relative power base, and (3) *collaboration* that leads to finding a win–win solution. The key requirement for conflict resolution is openness. By fostering mutual respect and trust, nurturing common interest to achieve project success, and focusing on commitment to task, most conflicts can be successfully resolved.

3.10 Informal Organizations

Beside the formal organizations, which is set up to achieve work efficiency, there are informal organizations in every business enterprise (Farris 2012). Typical informal organizations are of the following types:

1. *Social*: People form groups to pursue specific common interests, shared values, and beliefs; for example, beer clubs, bowling clubs, company outings, golf leagues, and tennis groups.

2. *Status*: People tend to be drawn toward persons well known for their technical skills, abilities, special accomplishments, experience, tenure, charisma, interests, peer recognition, and acceptance, and to want to associate with such achievers for their status.
3. *Group*: Coalitions form to advance shared interests. Fitness centers on site, day-care centers, toastmasters groups, foreign-language study groups, and bridge clubs are such examples.
4. *Location*: Depending on the flow of vital information, people tend to migrate toward critical locations, such as the offices of executive assistants, the desks of secretaries, and water coolers.

Engineering managers should be aware that informal organizations encourage additional bonding between employees. Because they contribute toward the smooth operation of an organization and members' job satisfaction, employee participation in informal organizations are generally encouraged.

3.11 Conclusion

Organizing is an important function of engineering management with a direct impact on the manager's ability to get work done efficiently. This function empowers a manager to choose the right organizational forms, be they teams, committees, task forces, functional or matrix arrangements, or other specific organizational structures. Managers assign appropriately skilled and compatible people to work together, each one having clearly defined roles and responsibilities, along with commensurate authority. Managers assign responsibilities to employees so that work gets done and employees can receive broadened experience. Managers allocate the right resources (such as skills, money, equipment, time, and technology) to accomplish the work efficiently.

Organizing is also important for enhancing the quality of work output. Flexible organizational structures allow companies to better respond to the changes of a dynamic marketplace. Certain organizational forms are superior to others in fostering creativity and inducing innovations. Multifunctional teams are known to be superior in handling conflicts at the interface between design and manufacturing or between R&D and marketing. Teams empowered by management to pursue specific assignments tend to be strongly motivating to the team members.

Engineering managers need to understand the power of organizing and use the function intelligently.

QUESTIONS

1. What type of organizational structure is best suited for developing a new product that requires a high level of specialization in several functions and for which the time to market represents a critical factor?
2. A materials manager suspects that the quality of work within her department has been deteriorating. She wants to introduce a program of change to advance quality. What steps should she take?

3. The company has recently concluded a multimillion-dollar contract to supply products to a Third World country. The first elite group of engineers from that country has just completed a two-month training course on maintenance and operations. The company's training manager reports that the level of skill and knowledge of that country's engineers was so low that no amount of training would ever enable them to properly operate and maintain the products in question. "It might be better for that country to buy a less sophisticated product from our competitor," the training manager suggests. What should the company do?
4. Six months ago, the company hired an engineer for his expertise in hydraulic drives. The decision to hire him was based on a product development plan that projected a need for such expertise. Market conditions have suddenly changed in favor of more sophisticated electric drives. The new engineer turns out to be very good in his area of specialization, but it is difficult to retrain him for other assignments in the company. Should the company discharge this engineer?
5. The company has been making most of its sales to a few large customers. The company president wishes to broaden its customer base. To do so may require changes in the company culture, the product line strategy, marketing and sales programs, and the service organization. How should the president go about making the required changes?
6. The company is considering a plan to upgrade its current product line. The cost of upgrading is high. There is a small company that has developed the technology required for this product upgrade. What strategy should the company follow if it wants to continue selling into its current market with the new, upgraded product?
7. As the company's sales are falling unexpectedly, the president asks you to chair a task force with the objective of developing solutions to correct the situation. Who do you want to be on this task force? How should the task force resolve this problem?
8. A loyal and high-volume customer has warned the company's marketing department that project X is extremely critical to their needs and that if this project is late, they may be forced to buy elsewhere. The project manager knows that the best estimates available to date from various in-house groups indicate that, at the current rate of progress, project X will be late by about six months. What should the project manager do?
9. Sally Lee, the engineering manager, delegates tasks as a good manager should. However, Mark Hayes, the engineering director, has the bad habit of calling up Sally unexpectedly to get detailed reports on various ongoing activities in Sally's department. Sally does not want to hold daily staff meetings in order to satisfy Mark's information needs because Sally is quite certain that asking her professional staff to stand by and make daily reports will definitely be counterproductive, as all of them are known to prefer their independence. What should Sally do?
10. In an organization offering a dual-ladder career progression system, technically trained people may opt to progress along a technical ladder instead of the traditional managerial ladder. How does this work? (Figure 3.11)

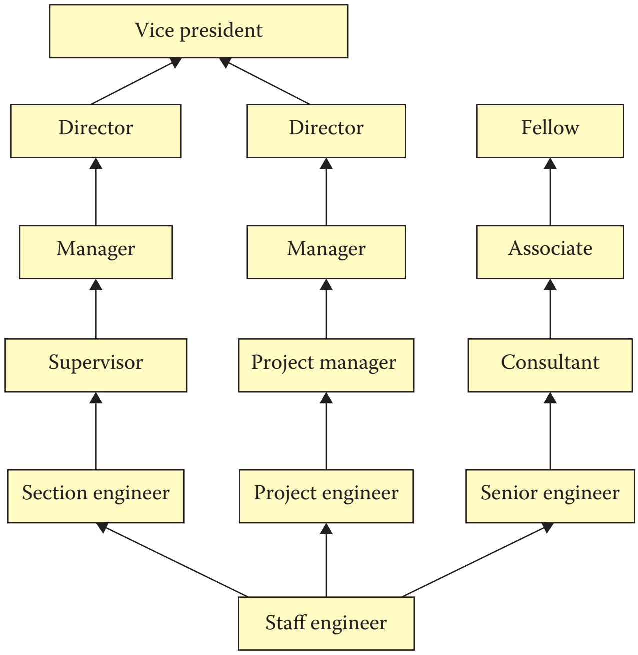

FIGURE 3.11
Typical career ladder in industry (Question 10).

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4

Leading

4.1 Introduction

Leading in engineering management refers to the function of an engineering manager that causes people to take effective action. After deciding what is worth doing, the engineering manager relies on communication and motivation to get employees to act. By selecting workers who are inclined to collaborate, the engineering manager motivates them to steadily add value to the company. In addition, skills training and attitude development may also enable employees to take action. In this chapter, five specific leading activities will be discussed, namely, deciding, communicating, motivating, selecting, and developing.

The true measure of the quality of an engineering manager's leadership is his or her demonstrated ability to guide and direct the efforts of employees to attain organizational objectives (Northouse 2015). A leader has vision, sets a good personal example, is able to attract and retain productive employers, motivates employees to use their abilities, and induces them to willingly do their best. Managers derive their authority from occupying higher positions within the organization. Leaders, on the other hand, have the power of influence over people. Their power is attained by earning employees' respect and admiration (Maxwell 2015). However, some leadership skills can be learned. Engineering managers with good leadership qualities are particularly valuable to their employers.

In this chapter, specific methods for making decisions are also illustrated. These include the rational method, decision-making by gut instinct, and decision-making in teams. Furthermore, a few special topics on leadership are to be addressed, including (a) leading changes, (b) advice for new leaders, and (c) guidelines for superior leadership.

4.2 Styles of Leadership

There are five major styles of leadership that are classified according to the attributes of either a *concern for people* or an *emphasis on tasks.* These are defined as follows:

1. *The nice guy*: Places too much value on social acceptance while neglecting technical tasks.
2. *The loser*: Neither obtains acceptance from others nor gets the job done.
3. *The compromiser*: Balances both the needs of people and task factors.

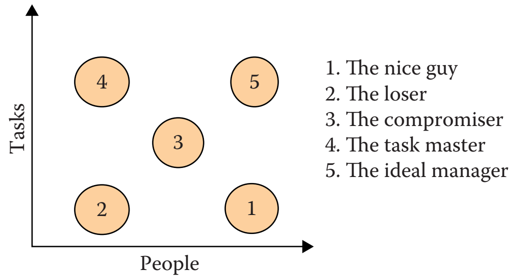

FIGURE 4.1
Leadership styles.

4. *The task master*: Is interested in getting the job done right without concern for human feelings.
5. *The ideal manager*: Gets the job done and at the same time makes everyone happy.

Figure 4.1 illustrates these styles. The principal style of leadership exhibited by a leader is largely determined by his or her personal characteristics derived from traits such as childhood experiences, parental impact, work habits, value systems, and others (Olson 2014).

Leadership style can also be identified as effective or ineffective, flexible or inflexible. Most leaders practice more than one leadership style in their daily work. Different styles are applicable to different people at different times (Lukiv 2015). Engineering managers are advised to vary their leadership styles in accordance with the needs of their employees (depending on whether the employees are experienced or novices) and the work situation at hand.

4.3 Leading Activities

The managerial function of leading includes performing specific tasks related to leading the engineering unit or department to achieve organizational objectives. The activities involved are outlined as follows (Kotter 1990):

1. *Deciding*: Arriving at conclusions and judgments with respect to priority, personnel, resources, policies, organizational structures, and strategic directions. Decision-making with incomplete data is the norm, not the exception.
2. *Communicating*: Creating understanding and resolving conflicts by talking, meeting, or writing to others.
3. *Motivating*: Inspiring, encouraging, or impelling others to take required action and creating workplace conditions to ensure work satisfaction. As leaders, science, technology, engineering, and math (STEM) professionals' dedication toward the project inculcates a sense of responsibility and urgency among the rest of the team.

4. *Selecting people*: Choosing the right employees for positions in the organization or for specific team activities.
5. *Developing people*: Helping employees improve their knowledge, attitudes, and skills.

Some of these tasks are relatively easy, and others are more difficult. Engineering managers need to practice them in order to become proficient over time in carrying out these activities. They also need to demonstrate the ability to conceptualize the future, identify unstoppable trends, and develop new ways to grow. Each of these activities will be reviewed in detail in the following sections.

4.4 Deciding

Making decisions is a key responsibility of engineering managers. Making high-quality decisions is the hallmark of excellent managers. The purpose of making decisions is to align the choices of project priorities, people, financial resources, technology, and relationships for the attainment of corporate objectives. As the engineering manager gains experience, the overall quality of his or her decisions is expected to increase (Health 2013; Krogerus and Taschaeppeler 2012).

Oftentimes, there is insufficient information available for guidance, or the future business or market conditions are very fluid and fuzzy. Under these circumstances, managers need to make spontaneous decisions based on intuition, gut instinct, and hunch. Obviously, if data are available, they make reasonable decisions based on systematic studies and logical analyses of them. Engineering managers are typically quite proficient in handling this latter type of decision-making, which follows the typical steps enumerated as follows:

1. Assessment of facts and evaluation of alternatives
2. Use of full mental resources
3. Emphasis on creative aspects of problem solving
4. Consistency in thinking
5. Minimize the probability of errors

Management decisions are usually difficult to make for a number of reasons. They involve problems and issues that are ill-defined, as they are wider in scope and affect more people than typical technical problems and issues. The required data and information may be insufficient or excessive, and there may be no time available to collect or interpret the data. The available information may be of poor quality, because it is based on guesswork, rumors, opinions, hunches, or hearsay. Decision-making involves human behavior, which is not always predictable. The nature of problems and issues changes continuously. The consequences of management decisions depend on opinions available, and as such, the consequences are also changing. Rarely does a perfect solution exist for management problems, since all options involve compromise, whose validity changes over time. Decision-making must also consider implementation, which in turn depends on the consensus and commitment of the affected people. Oftentimes, political considerations come into play as well. A critical decision may involve multiple layers of management or peer departments, and thus it requires coordination.

The following is a list of several decision-making guidelines useful to engineering managers:

1. Acquire decision-making experience, for example, by recognizing patterns and rules and by studying management cases.
2. Prioritize problems for which decisions must be made. Do nothing with problems that are perceived to have minor significance and impact on the organization. Avoid making decisions about issues that are not pertinent at the time. Delay decisions that cannot be practically implemented. Also, do not make decisions that ought to be made by others.
3. Follow a rational process to resolve a given problem and establish options to remove its root causes (see Section 4.4.1). Asking good questions is also the hallmark of excellent leadership.
4. Involve those who will be affected by the pending decisions in the decision-making process. Group decisions (see Section 4.4.5) are superior to those made by individuals from the standpoint of implementation. Such decisions, however, may take longer time to reach, and they usually represent compromises for all involved.
5. Make decisions based on available information and those assumptions that have been introduced. Check the validity of all assumptions and adjust the decisions accordingly. Take necessary risks and avoid becoming paralyzed by stress or uncertainty.
6. Delay making decisions until the last allowable moment, as the problems and available options may continue to change. Above all, meeting all deadlines with a decision is better than having no decision.

How can we judge the quality of a given decision? A simple way to find out is to raise the following three questions:

1. Has the decision achieved the stated purpose; has it corrected or changed the situation that caused the problem to exist in the first place?
2. Is it feasible to implement the decision; is it meaningful with respect to the required resources and the created value?
3. Does the decision generate noticeable adverse consequences or risks to the group or the company?

The decision at hand is regarded as good if the first two questions are answered with a "yes" and the last one with a "no."

As a rule, managers are expected to make decisions. However, there are circumstances in which managers should delegate the decision-making authority to the staff or work alongside them to come to a decision.

The following are problems or issues that should be handled by the managers only: (1) prioritizing tasks and projects, assigning office spaces, and defining group composition; (2) handling personnel assignments, evaluating performance, and taking job action; (3) dispensing budget allocation; (4) applying administrative policies, procedures, and regulations; and (5) dealing with highly confidential business matters that are specifically designated by the top management (e.g., compensation, promotion, corporate strategies, and new marketing initiatives).

Managers should include their employees when making decisions on the following problems or issues: (1) considering staff needs for development (e.g., attending professional meetings, technical conferences, seminars, and training courses, as well as committing to study programs at universities); (2) discussing policies and procedures, involving staff interactions with other departments; and (3) determining team membership (e.g., considering personality fit, skills compatibility, working relationships, and balancing workload). Decision-making authority should be delegated to staff members for the following matters: (1) techniques to accomplish assigned tasks or projects; (2) options to continuously improve current operations and work processes; and (3) social events involving staff participation, such as group picnics, golf outings, and Christmas parties.

As the saying goes, "practice makes perfect." Engineering managers should seek opportunities to constantly acquire experience regarding when, where, and what decisions are to be made. How decisions can be made is deliberated in the next section.

4.4.1 Rational Decision-Making Processes

A rational decision-making process is generally useful in facilitating decision-making for numerous problems or issues in engineering when an adequate amount of information is available (Eisenfuehr et al. 2010). It consists of the following set of logical steps:

1. Assess the apparent problem based on observed symptoms.
2. Collect the relevant facts. Usually, not all facts are available due to resource, cost, or time constraints. Facts must be related to five decision-making factors:
   a. Situation (what, how). The sequence of events leading to the problem and its conditions.
   b. People (who). Personalities, preferences, personal needs, and egos.
   c. Place (where). Significance of location.
   d. Time (when). Pressure to bring forth an immediate solution.
   e. Cause (why). Why the problem originally occurred, and why it occurred in one situation, but not in another.

   Past experience indicates that there are several good sources for identifying the relevant facts related to the problems at hand (see Table 4.1).

TABLE 4.1

Sources for Facts Related to Problems

Problem Categories	Sources of Useful Facts
Equipment	Plant operations personnel
Technical	Engineers with direct working knowledge
Customer inquiry	Sales people
Customer complaints	Service and sales personnel
Materials and parts	Delivery and inspection personnel
Product quality	Production staff
Customer preference	Marketing personnel
Market competitiveness	Marketing personnel

3. Define the real problem at hand and its inherent root causes by raising the following three questions:
   a. What is the deviation between actual performance and the expected norm?
   b. What are the desired measurable results in a problem-solving situation?
   c. What represents success based on well-defined metrics and the proper method of measurements?
4. Develop alternatives to address the root causes of the stated problems. Decision-makers ought to freely invite creative suggestions from people who have direct knowledge of the problem at hand, brainstorm in group settings (without criticisms or comments so as not to deter imaginative suggestions), and take into account both short-term and long-term impacts.
5. Select the optimal alternative. Decision-makers need to choose among the options to address the root causes, such as by applying the rational method (see Section 4.4.2). It is important for decision-makers to ensure that the chosen alternative will produce minimum adverse consequences to the company or unit. They also need to plan for contingencies and make midcourse corrections, if required, to secure the greatest probability of achieving the desired outcome. They should also avoid committing to a final choice prematurely before its implementation becomes feasible.

   A decision is nothing but the choice among several available options to solve a problem or address an issue. If there is only one option available, then no decision is needed.
6. Set a course of action to implement the decision. Once a decision is made, engineering managers should devise an applicable action plan to implement the decision. The manager must consider such details as policies that limit possible action, programs (the sequence of action steps), schedules (dates and milestones), procedures (the action steps carried out in an orderly manner), and budgets and expenses for equipment and manpower. Decisions that are not effectively implemented are useless.

4.4.2 Specific Rational Decision Analysis Tool

The Rational Decision Method is a renowned analysis tool available to support decision-making. It prescribes the following steps (see Table 4.2) to arrive at a rational decision:

1. Define a set of decision criteria needed for making the decision. The necessary criteria are those that must be met. For example, all entry-level engineering applicants must have undergraduate degrees in engineering to be considered for

TABLE 4.2

Rational Decision Analysis Method

Criteria	Weight Factor	Option A	Option B	Option C
Criteria 1	R	Go	Go	Go
Criteria 2	10	4	8	10
Criteria 3	5	6	10	7
Criteria 4	8	10	6	8
Total weighted score	—	150	178	199

employment. Some hiring companies may define a grade point average (GPA; e.g., 3.5 out of 4.0 maximum) as the cutoff academic performance level below which an applicant would not be considered. The sufficiency criteria are those that are not necessary, but are good to have. For hiring entry-level engineers, companies may specify these to be summer work experience, internship activities, project work, leadership positions held in student organizations, and others.

2. Rank order the sufficiency criteria by assigning weight factors ranging from 10 (as the most preferable) to 1 (as the least preferable).
3. Evaluate all options against each of the options identified as necessary decision criteria. For example, the options that meet the necessary criteria may be designated with the word "go."
4. Remove from further consideration those options that fail the necessary criteria.
5. Rank all remaining options relatively, with respect to specific sufficiency criteria. Assign a relative score of 10 to the most satisfactory and 1 to the least satisfactory option.
6. Repeat this scoring process for each of the remaining sufficiency criteria.
7. Compute a weighted score for each option by multiplying its relative score for a specific sufficiency criterion with its corresponding weight factor. Add up the weighted scores for all sufficiency criteria to obtain the overall weighted score for this option. Repeat the computation for each of the remaining options.
8. Compare the overall weighted scores and choose the option with the highest overall weighted score.

This method forces decision-makers to externalize all necessary and sufficiency criteria and to assign weight factors to all sufficiency criteria before making decisions. The chosen criteria must represent a *mutually exclusive and collectively exhaustive* set of criteria for the decision at hand. By ranking options against each of the defined criteria, all available options are properly evaluated in a rational, equitable, and comprehensive manner.

This method is particularly useful in a team environment where members may needlessly argue for specific options without externalizing their decision criteria and the relative ranking they have assigned to the criteria. Oftentimes, the advocates for a specific option make implicit assumptions that remain hidden and unknown to others on the team. In addition, personal biases may influence the relative scores assigned to the options when these options are evaluated against a given decision criteria. Experience has shown that the personal biases tend to become minimized when the relative scores are polled from all teammates during a meeting.

This method is also effective for decision-making on an individual basis. Some engineering managers tend to emotionally overemphasize certain decision criteria and downplay the importance of others. Again, having all decision criteria and their respective weight factors explicitly delineated will facilitate a rational decision.

Example 4.1

Bill Pickens, manager of the test division, called John Riley, the group head of mechanical testing, into his office and told him that there was a new opening for a manager of product development in the company. For John, it would be a promotion to a higher managerial rank with an appropriate increase in salary. However, the new position is temporary, in that it may be eliminated in a year. Although Bill hates to lose a very valuable worker like John, he wants to let John himself make the decision. The product development division has specifically requested that this opening be recommended to John. After having given it some thought, John decided to take the new position.

The next day, Bill Pickens and John Riley sit down together again to name a group head successor. Among the three section heads in the group, Dodd is the most experienced. However, Dodd is quiet and does not communicate well. He may have difficulty in selling testing services to others. Yeager is competent, but has made hasty decisions that have been very costly to the group. Bennett is ambitious and aggressive, but has poor interpersonal skills. They concluded that none could be immediately promoted to take over. Finally, they agreed to rotate the acting head job among the three, to test out each of them, since there is an outside chance that John may come back to his old position after one year.

Shortly thereafter, Bill Pickens was promoted out. John decided not to return to take Bill's position. Terry Smith was brought in to take over Bill Pickens's job as test division manager. However, before Bill Pickens left, he indicated to Yeager that Yeager would likely get the job, based on the results of the trial periods.

Terry found significant rivalry and ill-feeling between the three section heads. The group had low morale and poor productivity. Under such circumstances, Terry decided to appoint a new employee, Dennis Brown, to the mechanical testing head position instead of one of the three.

Did Terry make the right decision? Apparently, the job rotation idea failed. What would have been the right way for Bill Pickens to handle this problem?

Answer 4.1

The decision made by Terry was not the right one. The reasons are as follows:

1. The personnel situation was created by both Bill Pickens and John Riley's inability to make a staffing decision by choosing the best one among the three candidates and minimizing the impact of the new head's shortcomings. Rotating the acting head job created chaos due to infighting. Potential infighting should have been anticipated by experienced managers.
2. Terry's decision negated an implied management promise that one of the three would be promoted after a one-year trial period. This broken promise could be the basis of a future lawsuit.
3. The appointment of a new employee, without consultation with and concurrence of the three section chiefs, reflects a lack of sophistication on the part of Terry. It raises the issue of fairness and creates an employee loyalty problem. The three section chiefs are not likely to be motivated to work with the new person.
4. It is not known if Dennis Brown has the necessary technical and managerial skills to be more successful than any one of the three tried candidates.
5. The likely results are as follows:
    a. Lost management credibility due to broken promises and a lack of personnel staffing capabilities. (Riley neglected to groom a successor by correcting the perceived shortcomings of his chosen successor during the last five years.)
    b. Management is perceived to be lacking fairness in decision-making. (This will result in lower group morale and decreased employee loyalty. Employee turnover may increase as a consequence.)

The job rotation idea is a poor one. It was selected only because Pickens and Riley were not able to make good staffing decisions. They were looking for a perfect person,

TABLE 4.3

Making a Personnel Choice

Criteria	Weight Factor	Dodd	Yeager	Bennett
Minimum technical experience	R	Go	Go	Go
Experience	10	10	8	6
Communications skills	8	5	10	10
Decision-making abilities	6	10	5	10
Human relations skills	6	10	10	5
Total weighted score		260	250	230

TABLE 4.4

Making a Refined Choice

	Rank Without Improving Shortcoming	Probability of Correcting Shortcoming	Adjusted Total Score
Dodd	260	80	292 (=260 + 0.8 * 8 * 5)
Yeager	250	90	277 (=250 + 0.9 * 6 * 5)
Bennett	230	60	248 (=230 + 0.6 * 6 * 5)

and overlooked the possibility that most of the identified shortcomings could be easily compensated for or corrected.

What Pickens and Riley should have done was to make a hard choice in the beginning, either bringing someone in from the outside or promoting one of the three employees. Assuming that no suitable outside candidates were available, then rational decision analysis should have been used to come up with a choice, as shown in Table 4.3.

At first glance, Dodd appears to be the winner. However, as the candidates' weighted scores are rather close, the refinement step shown in Table 4.4 may be taken.

Adjustments are made based on the expected values of improving the relative score of the identified weakness from 5 to 10. The adjusted total score represents the final ranking of these three individuals, after each is allowed to minimize his weaknesses. Dodd remains the winner in this case.

Example 4.2

Due to global competition, the company faces a tough time in the marketplace, and so it must scale down its workforce. The board has offered the following options for the employees:

1. *Quit voluntarily*. This could be attractive to several bright young engineers whom the company does not want to lose.
2. *Last in and first out*. This could result in the loss of young and more versatile operators.
3. *Early retirement of those within 10 years of their normal retirement age*. This could cause a loss of engineers with valuable product knowledge.
4. *Reverse ranking in performance records*. This could lead to unfair selection, as the uniform performance appraisal system has been operating in the company only for the last few years.

What methods, or combination of methods, should the company use to reduce employment?

TABLE 4.5

Choosing the Method of Downsizing

Criteria	Weight Factor	Option 1	Option 2	Option 3	Option 4	Option 5 (1&4)	Option 6 (4&1)
Not to lose knowledge and experience	10	5	10	3	8	6	7
Easy for affected employees to find jobs	8	10	10	5	8	9.5	8.5
Easy for company to find replacements	8	5	10	3	8	6	7
Easy for company to avoid legal problems	10	10	9	8	5	8	6
Total weighted score		270	350	174	258	264	254

Answer 4.2

The company should use the rational decision-making method and assign weight factors to all the criteria. The relative score as displayed in Table 4.5 should be assigned to evaluate all options.

Based on the results obtained from Table 4.5, the method of last in and first out (Option 2) should be chosen to reduce employment.

4.4.3 Additional Support Tools for Decision-Making

A number of spreadsheet-based tools are commercially available to engineering managers to support their decision-making process. Examples of such tools include

- Forecasting (exponential smoothing, time series, and neural network computing) (Hyndman and Athanasopoulos 2013)
- Regression analysis (single variable and multivariable) (Chatterjee (2012)
- Risk analysis and project management (Fenton and Neil 2012; Yoe 2011)
- What-if solver (Slager 2014)
- Simulation modeling (Brandimarte 2014; Ross 2012)
- Decision trees (Rokach and Maimon 2014; DeVille and Neville 013), see the TreeAge 2015 software by httpe://www.treeage.com
- Optimization (linear programming and integer and dynamic programming) (Belegundu 2011)
- Artificial intelligence and pattern recognition tools (Marwala 2014; Frankish 2014)
- Expert or knowledge-based systems (Giarratano and Riley 2004; Tweedale et al. 2015)

Engineering managers should familiarize themselves with all of these decision support tools so that they can employ the right tools under the right circumstances (Ragsdale 2014).

Example 4.3

A certain company makes two products: P_1 and P_2. Each P_1 requires 5 kg of material M and 3 kg of material N. Each P_2 requires 3 kg of M and 3 kg of N. In the warehouse, there are 350 kg of M and 270 kg of N available. The profit is $50 for each P_1 and $40 for each P_2. What mix of P_1 and P_2 products should the company make and sell in order to maximize its total profit?

Answer 4.3

This is an optimization problem to be solved by linear programming:

$$\begin{aligned} &\text{Maximum profit} = 50 \times x_1 + 40 \times x_2 && \{\text{Objective function}\} \\ &\text{Subject to} \quad 5x_1 + 3x_2 <= 350 && \{\text{Constraints}\} \\ &\qquad 3x_1 + 3x_2 <= 270 \\ &\qquad x_1 >= 0 \\ &\qquad x_2 >= 0 \end{aligned}$$

Graphically, the solution method can be displayed as shown in Figure 4.2. Because of the four constraints, the solution space is bound by the area *OABCO*: *O* (0,0), *A* (90,0), *B* (40,50), and *C* (70,0).

As the profit line ($50 \times x_1 + 40 \times x_2$ = profit) moves to the right, the profit is maximized when it passes through the point B (40,50), the rightmost location it can take, while still satisfying the stated constraints. Thus, the maximum profit is \$4000(=50 × 40 + 40 × 50), and numbers of products P_1 and P_2 to make and sell are 40 and 50, respectively.

The simplex method is programmed to handle linear optimization programs with n independent variables.

Suppose we want to know more about the impact of material constraints on the company's profit. Let us assume that material *N* can be increased by 30 units, subject to the new constraint

$$3x_1 + 3x_2 <= 300 .$$

This new constraint, represented as a straight line $3x_1 + 3x_2 = 300$, intersects the straight line $5x_1 + 3x_2 = 350$ at the point *D* (25,75), which is not shown in Figure 4.2. The new optimum solution is then *D*, producing a new total profit of \$4250(=50 × 25 + 40 × 75). This new profit is \$250 over the previous total, because of added material *N*, which has a shadow price of \$8.33(=\$250/30).

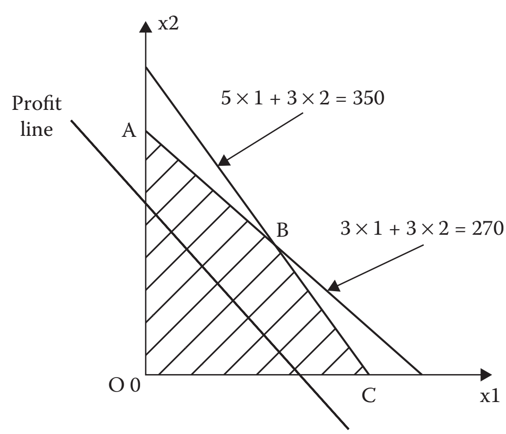

FIGURE 4.2
Linear programming problem.

4.4.4 Decision-Making by Gut Instinct

Since, up to middle-managerial levels, decision-making is mostly quantitative, the tools indicated in the preceding section are useful. However, at upper- and senior-managerial levels, problems and issues get much more complex and ambiguous. When such circumstances defy systematic analyses, decision-making is typically based on intuition and gut instinct (Cholle 2011).

Bob Lutz, president of the Chrysler Corporation, was reported to have made the decision in 1988, by pure instinct while driving alone along a country road, to develop and market a new sports car, the Dodge Viper. This car later turned out to be a great success. Using interviews with several other managers as source material, Hayashi (2001) studied the general intuitive decision-making processes.

What is gut instinct? According to Hayashi (2001), our minds process information all the time. Our left brain processes conscious, rational, and logical thoughts, whereas our right brain takes care of subconscious, intuitive, and emotional thoughts. Some people claim that they can tap into right-brain thinking by jogging, daydreaming, listening to music, or using other meditative techniques. Others have reported that they get innovative ideas while taking long showers or placing themselves in unfamiliar situations.

The theory of intuitive thinking claims that accumulated past experience enables some people to bundle information so that they can easily store and retrieve it. Experts further claim that such information is retrieved from memory by the observation of patterns. Professional judgment can often be reduced to patterns and rules. Accordingly, all other things being equal, people with varied and diverse backgrounds tend to be more capable of thinking intuitively and learning faster because they recognize more patterns. When using gut instinct, people essentially draw on rules and patterns that reside in their memories. Diverse backgrounds facilitate cross-indexing, allowing one to see similar patterns in disparate fields.

However, instincts can at times be wrong. People who make decisions intuitively are advised to secure constant feedback in order to minimize the impact of incorrect decisions and to learn from these decisions. Over time, the process of learning on the basis of feedback has the potential of improving the patterns and rules stored in the peoples' memory, thus enabling them to make better intuitive decisions in the future (Root-Bernstein and Root-Bernstein 2001).

Engineering managers at low- or middle-managerial levels should keenly observe how top-level leaders make important decisions and reflect on such decision-making processes, in order to update and modify their own decision-making patterns and rules.

4.4.5 Decision-Making in Teams

Typically, individual engineering managers make decisions by using one or more of the methods just described (analytical, rational, or intuitive). However, engineering managers may also elect to make decisions by using the inputs generated by teams. Under such circumstances, additional factors come into play, such as personality clashes, conflicts of interest, and coalitions or alliances among the team members, which affect the resulting decisions. Team leaders need to pay special attention to a set of additional guidelines that foster better decision-making in group settings.

Silver (2013) advanced the idea that the group decision-making process must be managed properly to consider social and organizational aspects. Doing so will secure the needed support for implementation, which ultimately determines the final impact of any decision. Three factors are important for the team leader to take into account when managing a group decision-making process, namely, conflict, consideration, and closure.

Group decision-making requires a set of leadership talents that are somewhat different from those demanded in other situations. These include (a) active solicitation of divergent viewpoints, (b) acceptance of ambiguity, (c) the wisdom to end a debate, (d) the ability to convince people of the merits of the decision made, and (e) the ability to maintain balance to embrace divergence and unity—divergence in opinion during the debate and the required unity of participants needed to implement the decision.

Engineering managers are encouraged to follow the preceding guidelines when managing team decision-making processes.

4.5 Communicating

The purpose of communicating is to create understanding and acceptance of the facts, impressions, and feelings being communicated. When communicating, engineering managers must have a clear purpose in mind and ensure that the message is understood and retained. A proper form of communication needs to be selected, such as a one-on-one meeting, phone conversation, written memo, staff meeting, e-mail, videoconference, web posting, or net meeting. It is advisable for the engineering managers to keep the communications channels open. They should be straightforward and honest, respect confidential information, welcome suggestions, anticipate resistance to changes, and dispel fears by disclosing full information (Adler et al. 2012).

There are five key actions to take to achieve efficacious communication: asking, telling, listening, writing, and understanding. These actions will be discussed next.

4.5.1 Asking

Engineering managers should proactively request information and not wait to be told. A lack of information can prevent understanding. Open-ended questions—those that cannot be answered with "yes" or "no"—should be raised to gain new knowledge. Voltaire said, "Judge a man by his questions rather than his answers." Good insights come from asking good questions. Great creative thinkers ask more questions. One needs to dig deeper and deeper until magic insights reveal themselves. Asking questions is to unpeel the layers of packaging to get to the real heart of the matter by repeating why, how, where, when, who, what, what if, and what else. The quality of the questions represents a gauge of the questioner's background, education, and depth of understanding of the issues involved (Palmer 2014; Sobel and Panas 2012; Marquardt 2014).

4.5.2 Telling

Telling means transmitting information (verbally or in written form, or both) for managers to keep employees informed about matters of concern to them, for employees to inform managers about problems and pertinent development (e.g., to avoid surprises that would trigger spontaneous and low-quality decisions), and for workers to pass information to their peers.

Engineering managers need to exercise judgment as to what to tell and what not to tell, as too much information could lead to overload and confusion and too little information could cause employee mistrust and poor productivity. A typical rule of thumb used in industry is that information is dispersed based on *the need to know*. Managers will share information freely if it is needed for performing specific work or has an impact on the individual's work environment (Walsh 2014).

4.5.3 Listening

Engineering managers need to work on their listening skills to enhance their understanding of both the words (spoken and written) and any possible subtext. Woodrow Wilson said, "The ears of the leader ring with the voices of the people." They should maintain their concentration by exercising self-discipline and rigorous control of their own urge to talk and interrupt (Alstine 2014; Ferrari 2012; Hartley 2014).

4.5.4 Writing

Written communications need to be *concise* (using the least number of words to express the maximum number of concepts), *logical* (allowing easy comprehension), and *pertinent* (focusing on the impact on the business purpose at hand). Check the writing advice offered by Felden (1964) with respect to readability, correctness, appropriateness, and thought. HBS Press (2003) offers seven principles of good writing: (1) having a clear purpose, (2) being audience-focused, (3) stating key message clearly, (4) staying on topic, (5) observing economy of words, (6) using simple sentences, and (7) considering the right delivery strategy. Consult the books by Strunk (2015) and Hacker and Sommers (2014) with respect to style.

4.5.5 Understanding

The ultimate goal of communication is to promote understanding—to hear with the head and to feel with the heart. Engineering managers need to recognize shared meaning (emotional and logical) and to assess the degree of sincerity by observing body language, intonation, and facial expression (Adler et al. 2013).

Several communication barriers exist and these barriers should be taken into account by engineering managers:

1. *Interpretations of words and terms*: Words are symbols or semantic labels applied to things or concepts. The same words may have different meanings to different people.
2. *Selective seeing*: Some people have the tendency to see only what they want to see and remain blind to other information unfavorable to the position they take.
3. *Selective listening*: Some people hear only what they want to hear by screening out information that may seem threatening to them, thus limiting their ability to appreciate different perspectives and points of view. Others in conflicts may want to understand only that which allows them to pursue their own self-interest.

4. *Emotional barriers*: All people have emotions. Engineering managers need to appreciate the fact that people's feelings are as important as their intellectual knowledge. Sometimes, people's attitudes and feelings may be so strong that they impair their understanding of what is being conveyed. Generally, personal biases will distort the understanding of what is being communicated.

The barriers just cited may cause the communications process to fail in creating the desired degree of understanding. Experience has shown that appeals to emotion tend to be understood and accepted much more readily than appeals to reason, analysis, or cold logic.

To communicate efficaciously, engineering managers are advised to pay attention to the following guidelines:

1. *Know what to say and say what is meant*: Engineering managers should focus on key messages when communicating. Avoid noise or meaningless sounds, pointless statements, and inconclusive remarks often used by people to impress others, but not to express themselves. Examples of such noise include "The answer is definitely a maybe" and "It is not probable, but still possible."
2. *Understand the audience*: Engineering managers should tailor their communication to the receiver's frame of reference—their beliefs, concerns from the job, background and training, attitudes, experience, and vocabulary.
3. *Secure attention*: Engineering managers should try to appeal to the receiver's interests; anticipate and overcome emotional objections (fear, distrust, and suspicion); talk in the receiver's terms; and lead from the present to the future, the familiar to the unknown, and the agreeable to the disagreeable.
4. *Obtain understanding*: An effective communication technique is to start with agreements and the statement of facts (not conclusions), use simple words (not ponderous, confusing, or abstract terms), and communicate in bursts (avoiding information overflow and knowledge digestion problems).
5. *Ensure retention*: The *rule of four* states the following: (1) Before trying to get an idea across, tell your receivers what you are going to say. (2) Say what you have to say. (3) Tell them what you said. (4) Get them to tell you what they have understood.

   Obviously, engineering managers must practice such a rule tactfully when the receiver happens to be a senior manager of the company, instead of a young intern engineer who may have just recently started to work.
6. *Receive feedback*: Engineering managers need to proactively pose questions and learn to listen in order to get feedback from what was communicated.
7. *Get action to enhance communications*: Engineering managers should have the receivers take action on the just-completed communication as a way of securing its impact. This could be in the form of a commitment by the receivers to take specific steps by agreed-on dates.

   Creating understanding is what communication is all about. Engineering managers need to practice asking insightful questions, conveying messages clearly, and listening attentively so that understanding is created at each and every communication endeavor.

Example 4.4

The company decided to move its engineering center to another location, since it was running out of space. The new location was to be modern and had been planned as a showpiece for the company. Management felt certain that the employees would welcome the move. Negotiations were started with several local governmental authorities for suitable accommodation.

To keep the workforce fully informed, it was agreed that the employees would be told that a move was to be made, but that as yet no site had been chosen.

This communication led to wide speculation among the engineering professionals as to the location of the new site, and various rumors circulated. Some engineers with families decided to look for alternative employment elsewhere, fearing that the new location would not be within commuting distance. Morale fell and productivity suffered.

Negotiations took longer than anticipated, and no suitable location had been found after six months. By then, morale was so low that the company decided to abandon its relocation plan altogether. To overcome the space problem, the company split the engineering group by putting a smaller team into another factory site nearby.

What went wrong? How would you have handled this case differently?

Answer 4.4

To communicate or not to communicate—that was the question. A well-intended, but premature relocation announcement induced anxiety in the minds of affected engineers. A lack of progress in site negotiations compounded these anxieties, causing low morale and decreased productivity, leading to an eventual abandonment of the plan.

It would have been better for the company management to keep the plan secret initially, negotiate for and decide on a specific site, and then have the company president announce the relocation plan in a town meeting. The announcement should have included:

1. The location of the new site, with emphasis on the advantages in transportation, health care, weather, and historical, cultural, and recreational attractions.
2. A request for the support of all engineers in making the relocation as smooth as possible. The purpose of the relocation is to provide a better facility for everyone. The company is investing x million dollars to support this move, which will allow for possible expansion in the near future.
3. The date by which relocation is to be completed.
4. A delineation of the company's plans to fund all relocation costs and offer assistance in selling and buying homes, if the relocation is more than 100 miles away. The company will also assist the affected spouses to find jobs at the new site.
5. The description of a human resources desk that will be set up to answer specific questions.

Example 4.5

Your department is going to institute a major change. Some members have indicated that they believe the change may be needed. However, in the past, members of the department have tended to resist changes that they did not initiate. The department as a whole has a good performance record. Discuss the advantages of the following alternatives:

1. Permit the members of the department to determine if the change is needed.
2. Let the group make recommendations, but see that your objectives are adhered to.

3. After the group discussion, adjust the goals, if possible, and monitor performance to see that the change is followed.

Which do you think is most appropriate? Are there other strategies that are more appropriate?

Answer 4.5

People resist changes unless they are convinced that the contemplated changes are necessary. They tolerate changes better if the changes are introduced gradually and they have had some say in making the changes.

Out of the three alternatives given, (2) is the most appropriate. Management must state clearly the objectives of the planned changes and how the attainment of objectives is to be measured. The members of the department should be allowed to participate in deciding how to achieve the stated objectives.

Company management must set the goals, which are not negotiable. Members of the department are not to be empowered to decide if changes are needed or not. Although the department has a good performance record, change may still be needed for achieving significantly better performance in view of the competition in the marketplace. Thus, alternative (1) is not appropriate.

The goals of the department should not be adjusted on the basis of what members of the department would like to do. Performance monitoring is a valid approach to ensure that the stated objectives are met. Thus, alternative (3) is also not appropriate.

In general, staff participation is useful to ensure active implementation of the decision made. Thus, a combination of alternatives (2) and (3) may be proper. Management specifies the objectives of the changes and the ways the attainment of these objectives are to be measured. Members of the department are encouraged to make recommendations regarding the best ways to implement the changes. The actions taken by the department are to be monitored constantly to make sure that the stated objectives are met, even if only gradually.

4.6 Motivating

The engineering manager secures results by motivating people. Examples of motivators include opportunities to do challenging, interesting, and important work; exercising leadership and position power; and gaining prestige and recognition. To motivate is to apply a force that excites and drives an individual to act in preferred ways. In general, emphasis is given to motivational forces that cause the individuals to willingly apply their best efforts (Bruce 2011: Stratheford 2012). As Ralph Waldo Emerson said, "Nothing great was ever accomplished without enthusiasm."

It is advisable for engineering managers to accept differences in personal preferences, values, and standards, and not try to change people. According to one theory, personality traits are usually firmed up at the early ages of four or five by environmental conditions. Managers should also recognize that every employee has inherent drives to fulfill their own needs, such as self-actualization, recognition, ego, self-esteem, group association, and financial goals (Tracy 2013).

4.6.1 Methods of Motivation

In general, engineering managers have several methods of motivation at their disposal (Mauer 2015):

1. *Inspire*: Infuse a spirit of willingness into people to perform most effectually by way of their own personality and leadership qualities, personal examples, and work completed.
2. *Encourage*: Stimulate people to do what has to be done through praise, approval, and help.
3. *Impel*: Force and incite action by any necessary means, including compulsion, coercion, fear, and, if required, punishments (such as demotion, job suspension, or termination).

The first two methods are well suited to motivate professionals, and the last one is not. Being assigned challenging work is a useful motivator for professionals.

4.6.2 Specific Techniques to Enhance Motivation

Engineering managers may implement the techniques outlined here to inspire and encourage professionals to act (Newman 2015).

1. *Participation*: Invite employees to take part in setting objectives and making decisions. Doing so will ensure emotional ownership and the utilization of specialized knowledge. Participative management is known to have a positive motivational impact on employees.
2. *Communication*: Set clear standards, relate the importance of the work, keep expectations reasonable, and respond to suggestions offered by employees.
3. *Recognition*: Give credit where it is due, as sincere praise tends to promote further commitment. Fair appraisals induce employee loyalty and trust.
4. *Delegate authority*: Trust the employees and do not overcontrol them. Achievers will seek additional responsibilities, and security seekers will not. Delegate what to do and leave how to do it to the individuals. Delegate technically doable work only to those who want it.
5. *Reciprocate interest*: Show interest in the desired results to motivate employees to achieve these results.

4.6.3 Innovative Strategies of Worker Motivation

Confucius says, “Reciprocity is the foundation of human relations.” One very forceful method of employee motivation is indeed to offer help needed by the employees, who will surely be inclined to reciprocate. The key is to define such needs.

The innovative strategies advanced by Green (2013) are built on the known assumptions that a person’s needs may be grouped into hierarchical levels, as follows:

1. *Physiological needs*: Hunger, thirst, and the need for clothing and shelter.
2. *Safety*: Protection from threats and danger.

3. *Social*: Giving and receiving affection, group membership, and acceptance by peers.
4. *Esteem*: Ego and self-confidence to achieve recognition.
5. *Self-actualization*: Continued self-development and realization of one's own potential.

A satisfied need no longer dominates the individual's behavior, and the next higher-level need takes over. But a higher-level need only arises when lower ones are already satisfied. The central premise of the model is that an unsatisfied need acts as a motivator. Accordingly, a need-based motivation strategy suggests that engineering managers should learn to understand the specific needs of their professionals at any given time and find ways to help satisfy these needs.

Experience has shown that the motivation strategies presented here can be helpful in motivating professionals who typically have high-level needs related to self-actualization and esteem.

1. Present a variety of work assignments perceived to be desirable and that offer the opportunity for personal growth.
2. Offer work that has a scope broad enough for the employee to develop self-expression and individual creativity.
3. Manage with minimum supervision and control, as professionals favor independence and individuality. Professionals tend to prefer having the freedom to make their own decisions and choose their own work methods for achieving the stated objectives.
4. Provide work that fully utilizes the individual's professional experience, skills, and knowledge.
5. Assign work that enables the employee to receive credit and peers' recognition. Examples include teamwork, publication of technical articles, patents, company awards, and activities in professional and technical societies.

On the other hand, pay and benefits have only a minor impact, as physiological needs do not represent a motivator for most professionals. Because the higher-level needs are never completely satisfied, engineering managers have ample opportunities to motivate professionals to act with their best abilities in achieving the corporate objectives.

Example 4.6

Company X recently installed an incentive system in the production department. Each person receives incentive payments (in addition to hourly wages) for any work done beyond the work standards established for each job. After one month, the production manager noted that there was only a meager increase of 4.5% in production. In your opinion, what might be the reasons for such a poor outcome?

Answer 4.6

The incentive program appears to have failed in realizing the projected benefit. This could be due to several reasons:

1. The incentive offered may be too small relative to the base hourly wage that these workers have been earning all along.

2. Management may have made the mistake of not having consulted with workers to understand their specific hierarchy of needs. Additional pay may not be a strong motivator to them in comparison with other nonmonetary factors, such as peer recognition, self-expression, social acceptance among peers, and others. It is known that team participation (such as a quality circle) has been a strong motivating factor for many production workers in the automobile and other industries.
3. If the production workers are unionized, the union leadership may have played a role in discouraging workers to compete against each other for pennies.

It would be worthwhile for the production manager to set the target for desirable productivity improvement at, for example, 10%, over the next 12–18 months. Then, the production managers should form a team that is empowered to develop recommendations regarding the specific ways to achieve the stated improvement goals in productivity. The team should be made up of workers on the plant floor, union leaders, production engineers, and others who have direct knowledge of the production process involved. By having participated in such teamwork, workers on the plant floor become part-owners of the resulting action plan. The resulting plan is more likely to be successfully implemented.

4.7 Selecting Engineering Employees

The long-term success of an engineering enterprise depends on the availability and effective utilization of employees' abilities, skills, and talents. It is equally important to note that job satisfaction is known to have a profound impact on employees' willingness to apply their skills to the best of their abilities (Arthur 2012; Farr and Tippins 2010).

Through employee selection, company managers have some control over employees' abilities, their willingness to apply their best efforts, and the extent of their job satisfaction. All companies would favor hiring employees who are productive and happy workers in corporate settings, firmly dedicated to their tasks, have excellent interpersonal skills, possess the team player mentality, receive sound basic training, and exhibit the capability to learn new things quickly.

4.7.1 Selection Process

Typically, the employee selection process includes the following steps:

1. *Define needs*: Specify the needs of the new positions by taking into account the immediate requirements and long-term growth demands of the organization.
2. *Specify jobs*: Compose a job description for each of the open positions to define the roles and responsibilities of the position holders, the position grade levels, and the minimum qualifications of the ideal candidates (i.e., levels of basic training and work experience).
3. *Acquire applicants*: Publicize job openings in newspapers, professional publications, company websites, employment agencies, social media, and Internet job sites to solicit candidates.

4. *Review and prescreen*: Select applicants by matching personal objectives with company goals and check documents and references carefully.

   For entry-level candidates who are recent college graduates with no professional experience, many industrial employers place a significant amount of weight on their GPA. Some companies have even specified a minimum GPA level as a prescreen criterion. This overemphasis on the GPA is probably due partially to an ignorance of better, more objective criteria than the GPA in assessing the mastery of basic course subjects. This overemphasis is also due to the notion that the GPA is a composite reflection of the level of personal responsibility and dedication, as demonstrated by an individual in doing his or her principal job of learning during college years.

5. *Conduct interviews*: Each applicant may be interviewed by several hiring managers. The basis of assessment is typically *studying the past to predict the future*. The quality of past work is a very good predictor for the future, as people are known not to change significantly for the better overnight. A few useful guidelines are enumerated here.

   a. Ask about the candidate's capabilities pertaining to the new position.

   b. Listen carefully to what the candidate says during the interview. Avoid spending too much time selling the job opportunity to the candidate.

   c. Prompt the candidate to describe his or her last job. Be cautious of candidates who speak negatively about their past employers.

   For example, a recent college graduate may complain loudly about his or her research-centered alma mater's negligence in undergraduate teaching and use it as a reason for the individual's poor GPA records. This individual may be likely to behave as a blame-shifting, finger-pointing, and irresponsible individual in a professional environment.

   d. Suggest that candidates tell you something negative that you should know about them. Look for honesty. Determine if the candidate is aware of his or her personal flaws, and what active steps have been taken to correct them.

   e. Urge the candidates to explain what they would do if they got in over their heads at work. An employee who turns to a colleague is a team player. An employee who turns to a supervisor behaves like a child. An employee who isolates himself or herself when in trouble can be extremely damaging to the business.

   f. Ask for specific examples that demonstrate the candidate's capabilities in creativity, innovation, and general leadership.

   g. Encourage candidates to describe their aspirations. Ask, "Where do you see yourself in five years?" or "What are your future goals?" Companies need employees who can grow and evolve over time. A candidate who does not have goals or ambitions may resist learning new skills or taking on additional responsibilities.

6. *Decide on job candidates*: Match the candidate's personality, technical capabilities, work ethics, values, and other qualities with those of the company.

Generally speaking, the selection process just described, which is widely practiced in industry, has not always yielded desirable results for employers (Murphy 2011). Typically, four to five hiring managers may interview an engineering applicant during a one-day site visit. For employers, the easy part is to assess the candidate's technical capabilities, as such capabilities are readily supported by documents (e.g., academic records, internship reports, thesis, publications, and reference letters from professors and company executives). The more difficult part is the assessment of the individual's soft skills, as discussed in the next subsection.

4.7.2 Soft Skills

Any employee's future success in an industrial enterprise is known to be strongly affected by their *soft skills* in teamwork, interpersonal relationships, leadership quality, collaborative attitude, mental flexibility, and adaptability. These soft skills are linked to the engineers' personality traits, psychological profiles, value systems, and deep-rooted beliefs. However, companies generally do not require candidates to undergo specific psychological tests, and most interviewers are not trained to assess candidates for soft skills (Gillins 2015; Wentz 2012).

Part of the difficulty in assessing the soft skills of engineers is brought about by the engineers themselves. Nowadays, most engineers, armed with the knowledge of interviewing guides, know quite well how to "talk the talk and walk the walk" in interviews. They have polished responses to almost any type of questions in interviews and are thus proficient in displaying the characteristics they believe many employers are looking for.

Results in the literature have indicated over and over again that most professionals who failed in industry—those who have been laid off or voluntarily quit due to personal dissatisfaction—were deficient in soft skills, not in technical capabilities. Future hiring managers need to learn more about how to assess the soft skills of candidates.

Some companies have devoted significant efforts to address this issue. Shown here are industrial practices that describe what two progressive companies (Mazda Motor Manufacturing Corporation (USA), Flat Rock, Michigan, and Diamond Star Motors Corporation, Normal, Illinois) have done to assess the soft skills of their candidates and the selection criteria they used when selecting these blue-collar workers (Hampton 1988).

1. *Interpersonal skills*: Ability to get along with people.
2. *Aptitude for teamwork*: Team dedication and participation, focus on the impact on the team and company instead of individual performance.
3. *Flexibility*: Learn several jobs, change shifts, and work overtime.
4. *Drive to improve continuously*: Make and take constructive criticism.

The basic strategy followed by these companies is to *pick the best employees and train them well*. It is noteworthy that "best" is defined by the soft skills of the candidates, not by their hard (technical) skills. These companies are known to have selected 1,300 candidates out of 10,000 applicants at a cost of $13,000 per person, using a multiphase process involving tests, exercises, and role-playing in group activities.

4.7.3 Character

In the last few years, the general public has found a renewed interest in business ethics, mainly sparked by reported questionable practices by companies such as Enron, Global Crossing, Adelphia Cable, Arthur Andersen, and others. Chapter 11 provides detailed discussions of various ethical issues. However, it is proper to note here that it serves companies better in the long run to hire employees with character and then train them to acquire the requisite technical skills to become productive (London 2013; Brooks 2015).

4.8 Developing People

Developing employees is another important activity of the managerial leader (Noe 2012). The objective of developing employees is to shape their knowledge, attitudes, and skills in order to enhance their contributions to the company and to foster their personal growth. Knowledge is the cognizance of facts, truths, and other information. Attitudes are habitual personal dispositions toward people, things, situations, and information. Skills are the abilities to perform specialized work with recognized competence.

In well-organized companies, managers are evaluated on the basis of several performance metrics, including how they have taken care of the development needs of their employees. To be successful, employees must demonstrate initiative in seeking to continuously improve their own knowledge, attitudes, and skills.

4.8.1 Employees

There are several ways in which managers may help develop employees. Employees may be prompted to follow the managers' personal examples of continuous improvement in knowledge, attitude, and skills. Managers may coach inexperienced employees on the job by demonstrating preferred ways of performing specific tasks. In addition, managers could enrich employees' work experience by institutionalizing a job rotation. If the company's budget and policy so allow, the specific employees may be sent to attend professional meetings, technical conferences, training seminars, and study programs at universities. Furthermore, team assignments may be used to permit a better utilization of the employees' talents and expertise to other critical projects, while offering them an opportunity to become known to a larger circle of peers within the company (Yukl 2012).

In training employees, managers need to emphasize employee participation, as the goal is to satisfy the employee's needs while simultaneously attaining the company's objectives. Employees should be appraised with respect to their present performance in determining what steps might be needed to qualify them to make greater contributions in the future. If the employee's current performance is deemed to be inadequate, managers need to be positive and forward looking in helping the individual recognize the need for self-improvement. By setting a personal example of continuous improvement, the manager is likely to positively motivate the individual to seek further development.

4.8.2 Successors

Besides training employees, managers are also expected, as a part of their managerial duties, to find suitable candidates within their organizations to succeed themselves sometime in the future (Ward and Aronoff 2010). This is consistent with career planning programs that some industrial companies are actively implementing to promote leaders from within, discourage turnover, and maintain corporate continuity.

4.9 Special Topics on Leading

Corporate change needs strong leadership. Leaders promoted into new positions will need to apply special strategies to succeed. Successful leaders share certain common attributes. The next subsection discusses the special topics related to the managerial function of leading.

4.9.1 Leading Changes

In twenty-first-century global economies, company-internal changes occur frequently and often in reaction to changes in the external environment. Changes are typically forced on companies by the market entry of new competitors, the declining market share position of the company, the emergence of new technologies threatening the company's products or services, declining company performance in different regional markets, (e.g., sales, gross margin, earnings, and net profits), shifting in customers' preferences, and other factors (Laurence 2014; Anderson 2013; Shea 2013).

Changes will usually require the company to modify its ways of conducting business. In general, changes are difficult to introduce because people like to stay in their comfort zones. After changes are introduced, they need to be sustained beyond a transformational period. Corporate changes demand strong leadership. According to Kotter (2012), there are two reasons why many transformation efforts fail:

1. Large-scale corporate transformation takes time. In one specific example, the maximum number of changes in a corporation was reached in the fifth year of transformation (Shannon 1980). Leaders must be patient in marshaling corporate resources to push forward (Figure 4.3).
2. Corporate transformation must follow a process of eight consecutive steps to succeed. Every one of these eight steps is critical, as failure in any one will affect the overall transformation performance.

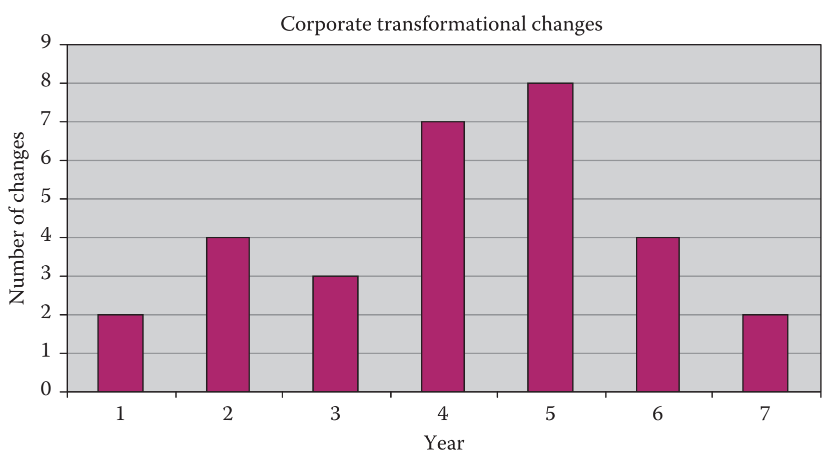

FIGURE 4.3
Corporate transformational changes. (Condensed and adapted from Robert E. Shannon, *Engineering Management*, New York: John Wiley, 1980, p. 203.)

The process of eight consecutive steps delineates essentially the success factors for transformational change. These eight steps are

1. *Establish a sense of urgency*: Leaders must examine the market and competitive realities and identify and talk about crises, potential crises, or major opportunities available in the global market. The goal is to convince at least 75% of the management that remaining in the status quo is more dangerous to the health of the corporation than launching in a new corporate direction.
2. *Form a powerful guiding coalition*: Major renewal programs often start with one or two people. But a leadership coalition must grow over time. In addition to the top leaders, there should be another 5 to 50 people committed to renewal. The group must be powerful in terms of titles, reputations, and relationships. Only when there are enough leaders in the senior ranks will the renewal process move forward. Leaders should inspire the group to work together as a team. The specific goal is to secure shared commitment to change by the top management and by the most influential people. A line position holder must lead the coalition.
3. *Create a vision*: A coherent and sensible vision is needed to help direct the effort to change. Leaders need to develop strategies to achieve that vision. The vision should be easy to communicate to stockholders, employees, and customers. Ideally, it should be explainable to an audience within five minutes and achieve their understanding and acceptance.
4. *Communicate the vision*: Transformation needs a lot of people to make it happen. Employees need to be persuaded and motivated to help make the changes. The vision needs to be repeated whenever there are opportunities—through newsletters, review meetings, training seminars, company picnics, and other means. Leaders should use every channel possible to communicate the new visions and strategies, teach new behavior by the example of the guiding coalition, and "walk the talk," as communication occurs in both words and deeds.
5. *Empower others to act on the vision*: Leaders need to do away with obstacles to change, modify systems or structures that seriously undermine the vision, and promote risk-taking and nontraditional ideas, activities, and actions. Examples of obstacles to remove include structure (narrow job categories), compensation and appraisal systems, and managers who refuse to change.
6. *Plan for producing short-term wins*: Leaders need to plan for visible performance improvements, create these improvements, recognize and reward employees involved in the improvements, and achieve at least some success within the first one to two years. Otherwise, the renewal effort may lose momentum.
7. *Consolidate improvements and procreate still more change*: Leaders need to use increased credibility to change systems, structures, and policies that do not fit the vision; hire, promote, or develop employees who can implement the vision; and reinvigorate the process with new projects, themes, and change agents.

   Leaders should resist declaring victory too early to avoid killing the momentum.
8. *Institutionalize new approaches*: Leaders should articulate the connections between new behaviors and corporate success, establish the means to ensure leadership development and succession, and anchor the changes in company culture (values, behaviors, and social norms) so that the changes continue into the next generation of top management.

The eight-step process just described is recommended for top-level engineering leaders who are planning to initiate and implement major corporate transformational changes. With minor modifications, this process applies also to midlevel engineering managers who may be called on to change the performance of a division or a department.

4.9.2 Advice for Newly Promoted Leaders

If a new engineering manager is hired from outside to take over a department or division, he or she might need to follow a special strategy during the transition period (e.g., the first six months on the job) in order to be productive. This is because going into an unfamiliar situation is akin to sailing in dense fog and only having forward visibility for a short distance (Bradt and Davis 2014).

New leaders often make a number of common mistakes. These mistakes include being isolated, having "the answer," not strengthening the team, attempting too much, trusting the wrong people, and setting unrealistic expectations (Belker et al. 2012). In order for an engineering manager to become effective in a new organization, Watkins (2003) offers specific advice consisting of seven rules, namely, leverage time before entry, organize to learn, secure early wins, lay a foundation for major improvements, create a personal vision, build winning coalitions, and manage oneself.

For newly promoted engineering managers, the leadership strategy just outlined serves as a useful guiding light during the initial six-month period of sailing through dense fog. Although the aforementioned recommended steps cover all important aspects of a new leadership job—technical, cultural, political, and personal—individual engineering managers may need to further customize these steps to fit their personal style, organizational needs, and the people involved in a given situation.

4.9.3 Guidelines for Superior Leadership

To become superior leaders, engineering managers are advised to focus on the following eight attributes, according to Cohen (2002):

1. *Maintain absolute integrity*: Any doubt about the leader's integrity will be reflected in the trust that others place in the leader.
2. *Be knowledgeable*: The leader should be technically excellent at what it takes to get the job done.
3. *Declare expectations*: The leader should let people know which work to perform and what results are expected.
4. *Display unwavering commitment*: The leader must demonstrate his or her clear commitment.
5. *Get out in front*: The leader needs to build, establish, and maintain a strong positive image. The leader should get out of the office to see what is going on (e.g., at the plant floor, marketplace, customer service center, and technology laboratories). The leader should also get out in front of the group to be seen, so that others know their manager is committed.

   General MacArthur gave this advice to a young battalion commander during World War II: "Major, when the signal comes to go over the top, if you go first, before your men, your battalion will follow you. Moreover, they will never doubt your leadership or courage in the future."

6. *Expect positive results*: Show self-confidence and work to get favorable results.
7. *Take care of people*: This is the basic reciprocity doctrine of Confucius: "If you take care of people, people will take care of you." Starbucks is said to practice this doctrine by taking care of their employees first (e.g., financially supporting their college education), then customers, and finally shareholders.
8. *Put duty before self-interests*: The mission and the employees must be more important than one's own self-interests.

The preceding list of attributes neglects to include the all-important quality of strategic thinking and the leader's capability to create vision. Without vision, a person with the aforementioned attributes is merely a hardworking taskmaster who is responsible, goal oriented, and socially assertive.

4.10 Conclusion

Leading is another key function of engineering management. It encompasses the specific managerial activities of making decisions and selecting, developing, motivating, and communicating with people. Carrying out these specific activities well will make an engineer into a strong engineering manager.

Decision-making plays an important role in the career of an engineering manager. In the engineering community, the rational decision-making method is regarded as a standard. Engineering managers need to become familiar with a number of other decision support tools so that the right tool can be fittingly applied to specific circumstances.

This chapter offered guidelines for engineering managers to become better prepared for the special cases of (1) introducing major corporate changes, (2) working as a new leader in an engineering management environment, and (3) achieving superior leadership.

Engineering managers are encouraged to practice various guidelines associated with leadership whenever they find opportunities to do so.

QUESTIONS

1. Preparation of the company product that was promised to a major customer is running late, and there is intense pressure on the production team to deliver the product. The director of production is eventually told by the company president to deliver, "or else." The director therefore decides to ship the product, even though it had not gone through all of its testing procedures. Members of the production team become upset due to their uncertainty about the functionality and reliability of the shipped product. The director, however, insists that "We will just have to take that chance."

   As the director of production, how would you have acted differently?
2. As advised by the company president, the sales department received a set of specific recommendations provided by an outside management firm to reorganize for maximum effectiveness. The sales manager believes that a few of the sales staff

may disagree with the recommended changes. The sales manager herself is also not fully convinced of the merits of all of the recommendations, but she wants to implement them, at least in part.

How should she proceed?

3. The engineering director of the company is called on to send one engineer abroad to assist in the installation of equipment. There are three qualified candidates, each working for a different manager under the director. The director knows that all three engineers will want to go, but their superiors will oppose any of them going for fear of losing time in completing their own critical projects. How should the director make the choice?
4. The marketing department needed to submit a proposal to a global customer, and it called a review meeting the next morning. By the time Bill Taylor, the design manager, was informed in the late afternoon, all of his design staff had left for the day and there was no one available. Bill Taylor decided to work on the proposal himself through the night so that he could talk with his design staff the next morning, one hour before the marketing review meeting.

   All of the staff agreed with the proposed design except Henry King, a senior staff member who is recognized as the most experienced and best designer in the group. His objections were that the current design was too complex and that it would take another week to modify the design to ensure its functional performance.

   In order to pacify him, Bill Taylor invited Henry King to come along to the marketing review meeting so that Henry King would feel the pressure that marketing was exerting on design. Unexpectedly, Henry King stood up at the marketing review meeting and reiterated all of his design objections, causing tremendous embarrassment to Bill Taylor and his superior, Stanley Clark, the design director. Bill Taylor became furious.

   What should Bill Taylor and Stanley Clark do?
5. Jerry Lucas is the division director. As branch chief, Bob Sanford reports to Jerry Lucas. Bob Sanford has four section chiefs reporting to him.

   Bob Sanford is technically competent, with extensive experience in solid rocket propulsion; he is also regarded as the best expert in this field. He is highly dedicated to his work, but inexperienced in managing technical people, as he has been on the job for only two years. Bob Sanford handles his subordinates quite roughly. He reverses his section chiefs' decisions without prior consultation with them. He demands that no information or data be transmitted to persons outside the group without his knowledge and concurrence. He also bypasses his section chiefs to go to people and encourages them to come to him directly with problems. Rumors have it that he places spies or informants within the group. As expected, he delegates no decision-making authority to his section chiefs and regards all of his section chiefs as technically incompetent. He creates an atmosphere of fear and suspicion, with low group morale.

   Bob Sanford does not report to Jerry Lucas candidly on project progress and on difficulties he encounters. He does not understand his own responsibility of building teamwork, enhancing group morale, and creating employee satisfaction while achieving the goals of his group. He is lacking the skills and willingness to resolve conflicts within the group.

Finally, the section chiefs as a group go in to see Jerry Lucas and complain about the lack of authority and the oppressive atmosphere in the section.

What should Jerry Lucas do? I should note that this problem was condensed and adopted from Shannon (1980).

6. The board of directors receives a proposal from a business partner to jointly set up an assembly plant in a Third World country. This new plant will assemble final products with key components made by the company. Financial terms are attractive and the future marketing outlook is bright. There is just one problem. The Third World country is not a democracy, has a poor human rights record, neglects to protect its own environment, and does not safeguard workers' rights. An investment placed by the company would boost this country's economy and thus the political position of its current dictator. Should the company accept the proposal? Explain why.
7. What are some important characteristics of effective leaders? Which of these characteristics are more difficult for engineers to acquire?
8. The plant manager noticed a need to lessen the amount of waste materials, which occur in the production process. A task force was set up, composed of the plant manager and two of her supervisors, to examine the problem. They met for three months and regularly published the task force objectives and findings on the plant bulletin board.

   The plant manager found, to her surprise, that the workers on the shop floor exhibited limited interest in the task force and ignored the bulletin board entirely. At the end of the three-month period, the task force came up with several excellent recommendations, which required changes in work practices. Most of the workers implemented the recommended changes very reluctantly, and some even secretly worked to sabotage the new practices. Eventually, all recommendations were withdrawn.

   What went wrong? How should the plant manager have handled this case?
9. The project was running late and the section manager thought that it was time for a pep talk with his staff. He realized that he was considered to be somewhat autocratic by his staff, but this time he thought that he would impress on them that he was really one of the members of the team and that they would work together as one in order to succeed.

   The section manager thought he made quite a good speech. He pointed out that the project was running late and that, if they failed, the customer could cancel the contract. He explained further that, as manager, he was responsible for the success of the project, and so everyone would be equally to blame for the failure of the project.

   Unexpectedly, a group of staff came in to see him a few days later to clarify whether they were all under threat of unemployment, should it turn out in the future that they were indeed late and the contract was canceled by the customer.

   What went wrong? What would you have done differently?
10. A regional sales manager suspected that one of her customers was having financial troubles. However, she was reluctant to mention it to her superior because she felt that she could be wrong. She kept quiet for several months, continuing to take large orders from this customer and hoping that the customer could recover from their

troubles. Eventually, the customer went bankrupt and defaulted on the payment of several large bills. What went wrong? What would you have done differently?

11. Company X selects someone who is weak technically, but very strong in group-process skills, to lead a team in developing a new engineering product. Would such a person be successful as a team leader? What can be done to ensure that the engineering product developed by the team will be satisfactory from the technical standpoint?
12. Conflicts between technologists and managers may arise when the technical professionals with the skills to make a decision have to deal with a manager, who has the right to decide. Why do such conflicts often exist in organizations wherein everyone works toward the same common goal?
13. Company X makes the decision to substitute aluminum for steel in a component of its product. What factors probably have contributed to this decision? At what managerial level would this decision most likely have been made?
14. As the department head, you urgently need to find an experienced person to fill a vacancy. The work involves close cooperation and coordination with others inside and outside of the department. Candidate A has exactly the experience required, but appears to be very unsociable. Candidate B has experience in a related job and seems to have a pleasant personality, though is not an extrovert. Candidate C has business experience in a different industry and is extremely sociable. All three candidates have scored sufficiently high on intelligence tests to qualify for the job in terms of general ability. Which candidate would you choose, and why?
15. Joe Engineer has just graduated from the University at Buffalo. He earned a 3.8 GPA for his master of engineering degree. Before he finished all academic work, he sent out numerous job applications and received three specific job offers, A, B, and C. All of them require him to make a decision for acceptance or rejection within one week.

    Company A has an annual sales revenue of $5 billion dollars and is located in New York City. The job of "engineer" pays $95,000 a year, plus full benefits (e.g., 401(k), health insurance, four weeks vacations per year, education assistance, and relocation assistance). The city living is, of course, exciting and fun, but very expensive. The company has a structured training program for new employees to become familiar with its operations. His future boss is friendly and acts professionally. Joe believes that he can get along well with him. The work is in line with his basic technical training. As it is typically the case with big companies, other employees in the department are all quite smart and the internal competition among coworkers is relatively strong. He envisions that he may be able to get a promotion to the next level in five years' time. New York City is huge and there are at least five competitors to Company A offering similar products/services in the city. Another potential benefit of working in New York City is that Joe may be able to meet a lot of interesting young people and find a future spouse.

    Company B is a $500 million midsize company located in Rochester, New York. The job of "engineer" pays $80,000 a year plus full benefits, which are similar to that of Company A. Rochester is a midsize city with some cultural and entertainment activities. Its cost of living is reasonable. Rochester is close to the Finger Lakes region, a well-known recreational area. The next large city is Toronto, which is about two hours away by car. The future boss is quite enthusiastic about Joe's employment at the company and is eager to welcome him. The work is of a technical nature, but offers some managerial development opportunities that Joe likes. Joe believes that he could be promoted in the next three years and allowed to assume a higher level of responsibilities thereafter. The city has only a few large companies, such as Xerox and Kodak, but no company that competes directly against Company B. Joe thinks that it may be a bit more difficult, if not absolutely impossible, to meet a lot of interesting young people in Rochester.

Company C is a $50 million small company located in Buffalo, New York, where Joe did some summer work during his school years. The job of "engineer" pays $70,000 a year and offers some benefits. The benefits are not as good as in either Company A or B. Buffalo is slightly larger than Rochester, but is still way behind New York City in terms of culture and entertainment activities. Like Rochester, Buffalo suffers from a declining industrial base. There have been no new companies relocating into the Buffalo or the Rochester areas in recent years. Company C has no competitors operating in Buffalo or nearby regions. Joe knows his future boss because of his earlier summer work at the site. The work is quite exciting, as the future boss views Joe as one of the bright new stars and shows a significant willingness to personally train Joe for higher-level roles and responsibilities. Being in a small company, Joe understands that he needs to face up to the challenges of getting involved quickly in many disciplines beyond the principal one that forms the basis of his master's degree. Because Buffalo is also a regional city, Joe believes that it could be hard for him to meet a lot of interesting young people and subsequently find a mate.

Which job would you elect to accept? Explain the detailed decision-making methodologies and reasons that you used to arrive at your decision.

16. Preparation of the company product that was promised to a major customer is running late, and there is intense pressure on the production team to deliver the product. The director of production is eventually told by the company president to deliver, "or else." The director therefore decides to ship the product, even though it had not gone through all of its testing procedures. Members on the production team become upset due to their uncertainty about the functionality and reliability of the shipped product. The director, however, insists that "We will just have to take that chance." As the director of production, how would you have acted differently?

Appendices

Appendix 4.A: Factors Affecting One's Influence on Others

This section discusses the various factors known to affect a person's influence on people. It is advisable that the engineering manager pay attention to them (Cialdini 2006).

1. *Credibility*

   A person's credibility is based on the following six attributes:

   a. *Composure (ways to handle oneself)*

      A degree of poise, stability, and patience; skills to handle a crisis situation effectively; humor under stress; self-confidence; and ability for public speaking are important attributes. Composure is the most important factor affecting credibility in the short term.

b. *Character*

Integrity and honesty (not lying, not cheating, attempting to do things above board, and maintaining high-moral standards); cooperative spirit, and professional behavior—return all phones calls and respond to all mail; keep promises, have an open and forthright attitude, and be fair in all situations. Character is the most important factor affecting credibility in the long run (integrity and honesty in professional versus private matters).

c. *Competence*

Technical (job-specific skills, experience, and training), managerial (planning, organizing, leading, and controlling), and visionary (capability to envision the future with strategic thinking). Table 4.A1 displays the competence factors that exert an influence on superiors.

d. *Courage*

Commitment to principles; the willingness to stand up for beliefs, challenge others, and admit mistakes; and the ability to make tough decisions under uncertain conditions and accept responsibility for the consequences.

e. *Conviction (beliefs)*

Commit to the vision, demonstrate passion, and show confidence in the direction being pursued.

f. *Care for people*

Know people (family, aspirations, current and future needs, favored learning modes, upward mobility, etc.), treat people with respect and dignity (listening to understand), comment only on issues and situations and not on the person, and be a team player.

2. *Personal power (independent of position power)*

Personal power is affected by the following three factors:

a. *Personal attributes*

Physical appearance and size, drive, dedication, and personal values.

b. *Knowledge*

Common sense, historical perspective, political knowledge needed by others (how to get things done through which doors, by what means, and with whom—otherwise known as tricks of the trade).

c. *Relationships*

Business connections and power by association.

TABLE 4.A1

Competence Factors on Influence Exerted Upwards

	First-Line Supervisor (%)	Mid-Manager (%)	Executive (%)
Technical	70	30	5
Managerial	25	40	25
Visionary	5	30	70

3. *Variable leadership style*

   Leadership style needs to be varied in accordance with the circumstances involved. In general, there are four situations that each requires a different style of leadership. (See discussion in Section 4.2.)

   The influence exerted on people by an engineering manager is affected by his or her credibility, personal power and leadership style. Engineering managers need to do the right thing at the right time and place, to the right people, for the right people, or with the right people.

Appendix 4.B: Motivation of Mission-Critical People

In the competitive world today, all companies struggle to attract and retain innovative knowledge workers who are critical to the mission of their operations. To be successful, companies in general, and engineering managers in particular, need to tailor specific motivation strategies to the needs of individuals. In general, most knowledge workers have the following types of needs:

1. *Need for power (40%)*: Setting goals and offering positive recognition to allow one to stand out and be unique
2. *Need for affiliation (40%)*: Focusing on mission, vision, and the difference the individual can make in teams
3. *Need for self-achievement (20%)*: Offering task variety, learning, development, and growth opportunities

Nortel Networks and Cisco Systems Inc. experienced high turnover (about 40%) in their information technology sector. Surveys indicate that people with mission-critical jobs left because of three specific deficiencies:

1. *The work itself*: Meaningfulness, relevancy, learning opportunity, enjoyability, variability, etc.
2. *Appreciation*: Thanks, recognition; they were never told that their jobs were mission critical.
3. *Money*: Many left for more money.

The preceding list of needs and the types of deficiencies causing knowledge workers to want to leave are consistent with the Maslow need hierarchy model discussed in Section 4.6.3. It is obvious that unsatisfied needs will strip employees of motivation if they stay unsatisfied for long. Under such circumstances, knowledge workers are likely to migrate to places where they can satisfy these unmet needs.

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5

Controlling

5.1 Introduction

The function of controlling in engineering management refers to activities carried out by an engineering manager to assess and regulate work in progress, evaluate results for the purpose of securing and maintaining maximum productivity, and reduce and prevent unacceptable performance (Reichmann 2011). Although the bulk of the controlling activities appear to be of an administrative and operational nature, controlling has strategic importance. To efficiently implement any assignment project, program, or plan, managerial control is crucial. Any forward-looking strategic plan becomes of questionable value if its implementation is poor. Furthermore, without adequate control, managerial delegation is ineffective, rendering the managerial leadership less effective. The function of controlling also contributes to corporate renewal by pruning the dead wood, if needed.

Skills to recruit the best employees and keep them motivated and productive are critically important to managers. There are eight recommended ways to develop a productive workforce, including (1) assessing performance, (2) coaching, (3) dismissing an employee, (4) giving and receiving feedback, (5) hiring, (6) managing difficult interactions, (7) managing workplace stress, and (8) retaining valued employees.

Engineering managers exercise control by carrying out the specific tasks of setting standards, measuring performance, evaluating performance, and controlling performance. In addition, this chapter addresses the manager's control of time, personnel, business relationships, projects, and company knowledge.

5.2 Setting Performance Standards

To set standards is to specify criteria by which work and results are to be measured and evaluated. Setting performance standards defines the expected outcome explicitly. It is important for both the company and its employees to distinguish between performance grades of "outstanding," "better than average," "average," "below average," and "unacceptable," and to understand how performance is measured. Here, "average" is defined as the generally expected performance level for the job at hand by persons with adequate training and dedication (Cizek 2012).

Setting standards provides specific guidelines for exercising authority and making decisions. Standards represent a yardstick for measuring the performance of employees and units (such as cost centers and profit centers). Proper standards facilitate employee self-evaluation, self-control, and self-advancement.

Standards are typically established in the form of how many (number of units), how good (quality, acceptance), how well (user acceptance), and how soon (timing), as imposed by the company management, the customers, or the marketplace. It is worth noting that current trends of setting standards emphasize the inclusion of customers' perspectives.

There are standards of technical, historical, market, planning, safety, and equal employment opportunity (EEO) types. Technical standards specify metrics related to quality, quantity, mean time between failures (MTBF), maintenance requirements, and so on. Historical standards are based primarily on past records. Market standards are those related to competition, sales, return on investment (ROI), earning expectation by securities analysts, and other factors. Planning standards mostly relate to the strategic and operational needs of the company. They address topics such as objectives, programs, schedules, budgets, and policies. Safety standards refer to the metrics related to the safe operation of the company's facilities. Government programs such as the U.S. Occupational Safety and Health Administration (OSHA) promulgate some of these safety standards. EEO standards are specific practices related to affirmative action for the purpose of achieving fairness among a diversified workforce.

Effective standards are characterized as being company sponsored, measurable, comparable, reasonable, and indicative of the expected work performance on an objective basis in order to promote employee growth, while considering workers' human factor inputs and securing their understanding and acceptance.

Example 5.1

The engineering director asks her managers whether they have any nominations for promotions from within their respective departments. The maximum number of promotions allowed for the entire division is two. The nominations must be selective and only for people whose performance has been outstanding. One manager thought his whole team had been outstanding, so he recommended all 10 for promotion. He reasoned, "It is better for the morale of the team that they know that I support all of them fully. If the director now promotes 1 of the 10 or none at all, then they will not feel so bad knowing that at least I have thought them all worthy of being promoted."

What should the director do?

Answer 5.1

The director should call the manager in and reprimand him for not following the instructions given, for being selective in nominating candidates for promotion, neglecting the delegated responsibility of evaluating the performance of his staff fairly and objectively, and wanting to pass on his own responsibility to his director so as to be the "good guy."

She should order the manager to repeat the nomination process and come up with a rank-ordered list of outstanding performers for possible promotion within two days. If he refuses to do so, this will be registered as one incidence of disobedience. Repeated offenses of this type can lead to immediate discharge.

There are quite a few barriers that prevent good standards from being readily developed. Standards may be too subjective, as technically strong engineers tend to set unrealistically high standards for themselves and others. If standards are set too high, workers may become demoralized and fearful of not measuring up. On the other hand, if standards are set too low—not challenging enough for the workers—management will lose the respect of employees. Standards may be confusing and may not clearly indicate the criteria for excellence. Standards may be qualitative and vague and thus subject to divergent interpretations by different people. Standards may also be set without proper consideration of the constraints related to resources and implementation.

A useful way for companies to set proper standards is the practice of benchmarking, discussed in the next section.

5.3 Benchmarking

Benchmarking is a method of defining performance standards in relation to a set of internal and external references (Bogan and English 2014; Bogetoft 2013). There are two types of benchmarking:

1. *Internal benchmarking* uses references internal to a company to set performance standards, as illustrated by the following example. Company X has achieved a productivity of $150,000 per employee in 2014 and is determined to continue improving performance on a yearly basis. The company president sets a new performance standard for the year 2015 at $165,000 per employee, a performance level of 10% higher than the previous year.

   Internal benchmarking is convenient to apply, as it offers a reasonable, short-term performance assessment. However, it may create a false sense of corporate well-being, as the resulting performance standards, in the absence of an external reference, may be deficient in the long run. That is, for Company X, the 10% productivity increment may be inadequate, or even outright dangerous to the long-term health of the company, if the industrial average productivity gain has been 12% per year in the past, and some competitors of Company X are aiming at 15% for the coming year.

2. *External benchmarking* uses references external to the company to set performance standards. The following examples illustrate its applications:
   a. *Financial ratios*: Assuming that the gross margins of many service-oriented public companies are in the range of 35%–40% for the last several years, as published regularly by Wall Street securities firms, then setting the gross margin target for a specific company at the 40% level for the immediate future year is a performance standard defined by external benchmarking. Setting the gross margin at 40%, if subsequently met, will ensure that the company will be among the best performers in its industry (Rist and Pizzia 2014).
   b. *Performance metrics*: Many metrics are published in business literature to evaluate performance related to production, product delivery, quality control, time to market, customer service, reliability, customer problem solving, and others. Using these known metrics as references to set performance standards makes explicit the relative competitive position of a company (Okes 2013).
   c. *Best practices*: Another set of important external benchmarks is called *best practices*. Table 5.1 lists a number of subject domains for which best practices have been published in business and industry.

      These are work processes or procedures perfected and upgraded by various companies over the years to address specific problems and issues in engineering, production, marketing, strategic management, business development,

TABLE 5.1

Sample Publications on Best Practices

No.	Best Practice Subjects	Publications
1	Project management	Kerzner (2010); Biafore (2012)
2	Organizational development	Carter et al. (2001)
3	Time management	Hoover (2009)
4	Manufacturing	Hull (2010)
5	Back office operations	Khalid (2010)
6	Teamwork	Salas et al. (2013)
7	Human resources management	Gottlin (2015)
8	Quantitative methods	Osborne (2007)
9	Planning and performance management	Axson (2010)
10	Achieving goals	Schienle (2007)
11	Communications	Kranz (2007)
12	People management	Silverstein (2007a)
13	Motivating employees	Silverstein (2007b)
14	Performance evaluation	Silverstein (2007c)

and other areas of corporate governance. These are extremely valuable "tried-and-true" methods to achieve useful results and add value to the companies. Those companies that are too undisciplined to consistently apply best practices in carrying out their corporate activities will soon discover that they have become less and less competitive over time.

d. *Critical success factors*: Serving well as external benchmarks are critical success factors, the necessary and sufficient conditions for achieving success in specific business management, engineering, production, and marketing domains. These factors are derived from the successes and failures experienced by companies in various industries. Having a clear understanding of these factors allows the company management to make strategic choices regarding pursuing business in new directions, initiating new products/services to gain advantages, and capturing opportunities in new markets by optimally applying corporate strengths while minimizing any exposure of weaknesses (Mihaescu 2013).

e. *Target pricing*: In recent years, some companies have successfully applied the technique of target pricing, another external benchmarking method, to achieve success in the marketplace (Nizam 2014). First, the company conducts a survey to determine the current prices of products that are in direct competition with the new products that the company is planning to develop. Using these prices as references, the company sets a target selling price (such as 20% below the prices of the competitive products) for its new product. Then, the company deducts the required gross margin for the company to sustain itself while meeting the shareholders' expectations. The resulting figure is the *cost of goods sold* target (the cost target) for the company's new yet-to-be-developed product. The cost target is then imposed on the company's production and engineering departments as a performance standard for developing the new product. Funds are available for developing the new product only if the cost target can be met. This is tantamount to an *innovation under duress* model of management control. The resulting new product is then more or less ensured a cost-competitive edge in the marketplace.

Traditionally, bringing a new product to the marketplace follows a sequential process. First, the product is designed by engineers on the basis of inputs from marketing. Then, it is redesigned by service engineers for serviceability to customers. Afterward, it is redesigned again by production engineers for manufacturability. Finally, it is mass produced, and its final product cost is then accurately estimated. The company management adds the gross margin to set the product price. At each step, engineers tend to introduce contingencies, or "cushions," to ensure that the work is done properly within their respective units. However, often this sequential process leads to products that are not cost-competitive in the marketplace.

In fact, the basic concept of target pricing can be applied to many other corporate activities for the purpose of ensuring that the company remains competitive. This is particularly pertinent to the current business environment, which is changing rapidly due to new technologies and becoming increasingly globalized.

f. *Balanced scorecard*: Many companies are known to have monitored corporate performance by using, primarily, financial metrics on activities related to the past (see Section 7.6). Progressive companies have started to devise a balanced set of performance metrics to properly monitor additional company activities that also have a profound impact on its future success (Niven 2014).

Balanced scorecards are attempts to accomplish this objective. Examples of such forward-looking performance metrics include the establishment of the percentage of company business generated by products introduced in the last five years; the percentage or amount of corporate funds spent on projects initiated in the last five years; the number of patent disclosures, patent applications, and patent awards in a given year; the number of new supply chain partners engaged in the last five years; the percentage of sales realized from new customers acquired during the past year; and the fraction of product cost arising from new technologies adopted in the last five years. It is self-evident that setting adequate, forward-looking standards based on both present and future performance measures helps guide the company to success over the long run.

5.3.1 Sample Benchmarking Metrics

Many sets of performance metrics are available from business literature. Table 5.2 contains selected samples of metrics used in various business domains (Ray et al. 2015).

5.3.2 Limitations of Benchmarking

Benchmarking is useful, but it has certain limitations. For example, some reference data may not be available, and in such cases, estimates must be made. This may cause the value of such benchmarks to be less robust. Benchmarking metrics are mostly based on past performance, and they can hardly predict the future. Nor can they be used to predict new competition. However, even with these limitations, past-oriented benchmarks are still valuable to some extent; as Confucius says, "Studying the past may lead to a better understanding of the future."

TABLE 5.2

Sample Performance Metrics

Domains	Metrics
Financial	ROI (return on investment)
	ROA (return on assets)
	ROS (return on sales)
	Debt-to-equity ratio
	Number of inventory turns each year
	Number of units produced per employee
	Number of units produced per hour
	Sales per employees
	Profit per unit of production
	Break-even volume
Nonfinancial	Average number of defects detected by customers in the first month of ownership
	Average number of defects detected during manufacturing and repair
	Hours lost to production due to unscheduled maintenance
	Work in progress in the plant
	Number of machines per worker
	Length of time to change a machine or introduce a new operation
	Number of job classifications in the plant
	Amount of materials made obsolete by model changes
	Average energy consumption per unit of production
	Rate of absenteeism in the workforce
	Number of months required to introduce a new product model
	Number of engineering change requests during a new product development program
	Number of units produced prior to a model change (batch production)
	Time metrics (response time, lead time, uptime, downtime, etc.)
Product related	Parts count
	Number of material types used
	Material use in each component
	Assembly process used in production
	Service quality: field repair versus field replacement
	Failure-mode effect analysis
	Quality of product as experienced by customers
	Long-term durability of product
	Fraction of sales to repeat customers
	Company responsiveness to service requests

Example 5.2

Product quality has many dimensions. Which dimensions of product quality have the most impact on the product's success in the marketplace?

Answer 5.2

According to Kenyon and Sen (2014), product quality has eight dimensions:

1. Performance (operational characteristics)
2. Features
3. Reliability

4. Conformance to design specification
5. Durability
6. Serviceability
7. Aesthetics (look and feel)
8. Perceived quality (affected by brand name and company reputation)

Which of these quality dimensions affect the product's success in the marketplace will depend on the type of products involved:

A. Automobiles—(7), (8), (1), (6)
B. Consumer products—(8), (1), (6), (3)
C. Industrial gases—(1), (3), (6), (5)
D. Office supplies—(1), (8), (7)
E. Home appliances—(3), (6), (1), (5)

5.4 Measuring Performance

After the performance standards are set, the next step of management control is to measure performance. Performance measurement refers to the recording and reporting of work done and the outcome attained. Managers take the following steps to measure performance: collect, store, analyze, and report information systematically; compare the performance with established standards; and issue reports such as data summary, collection of results, and forecasts to document findings.

Performance measurement may be carried out by time study, work sampling, and performance rating, among others (Falcone 2013; Aquinis 2012) for routine work, such as that on factory floors. The performance of professional workers needs to be measured with respect to the contributions made toward the attainment of the company's short- and long-term objectives. All measurements must be factual and accurate in order for them to serve as a valid basis for performance evaluation.

5.5 Evaluating Performance

To evaluate performance is to appraise work in progress, assess the completed job, and provide feedback. The following steps are usually taken to evaluate employee performance: establish limits of tolerance, note variations (deviation within the tolerance limits) and exceptions (deviation outside of the tolerance limits), provide recognition for good performance, and give timely, proper credit, if justifiable. Voltaire said, "Appreciation is a wonderful thing. It makes what is excellent in others belong to us as well." Paying attention to deviations encourages employee self-appraisal, fosters initiative, and enhances managerial efficiency.

A rating method often used in industry is to rank an employee in one of five categories: (1) outstanding, (2) above average, (3) average, (4) poor, and (5) failure. Category ranking is based on performance metrics that are specific to the individual. More often than not, in order to indicate the importance of these performance metrics to the company, top management will assign and publicize the weight factors associated with all performance metrics. A weighted score, similar to that calculated by the Rational Decision Method discussed in Section 4.4.2, is then determined for each employee. The weighted score and a written statement are then submitted by the manager to his or her superiors at the next higher management level for review. Once the approval of higher management is secured, these evaluation results become the official basis for salary administration and promotional considerations in the future.

It is quite obvious that this type of rating system has basic weaknesses. Some managers may suffer from a "halo effect" and assign an employee the same rating for all performance metrics. Others may be handicapped by a "recent effect" in that they are predominately influenced by recent events. By nature, some managers are more lenient than others, resulting in different interpretations of the grade "outstanding performance." Furthermore, the competitive nature of getting one's own employees promoted sooner tends to cause inflated ratings. To exert some control over this potentially chaotic situation, a few industrial companies are known to have advised department managers to steer the overall evaluation results toward a Gaussian-type distribution, which places the majority of employees in the "average" group and only about 5% and 15%, respectively, in the excellent and above-average groups (Gray 2015).

At the annual appraisal time, the individual employees will be notified of the approved evaluation results. In general, feedback from the individual employees is customarily solicited and documented. If the individual employee disagrees with some or all parts of the evaluation, his or her written comments are incorporated into the official evaluation files, which will be reviewed again by superiors at the next higher management level. If deemed proper, the approved evaluation results may be modified. The needs for the individual's future development are also discussed and noted. Specific goals of development are then agreed on as a gauge for monitoring the individual employees' progress at the next annual appraisal time.

The "average" level of performance is defined as the level of performance that can be generally expected of a person with adequate training and dedication in a given position. To be rated as excellent or above average, one must perform extraordinarily well and produce an unexpected positive outcome, which has a recognizable impact on the company's objectives. Poor performance is usually associated with work that is not meeting the acceptable quality standards, exceeding the approved budget, not completing the work on time, and/or suffering from problems related to communication, personality conflicts, devotion to work, interpersonal skills, or other deficiencies.

Should the performance of an employee be rated as poor or failure, his or her manager must initiate action to correct such performance in a timely manner.

5.6 Correcting Performance

To correct performance is to rectify and improve the work done and the results obtained. The performance evaluation may show that the quality of the employee's work is below expectation. Reasons for performance deficiencies may include a lack of known performance standards or feedback, not possessing the required technical capabilities to perform the tasks at hand, or not having a good work ethic and personal initiative (Fournies 1999).

Employees' mistakes should be corrected by focusing on future progress and growth. Employers should take short-term action to overcome deficiencies, such as getting assistance from outside consultants or hiring temporary workers. To avoid repeating the noted deviations, long-term-oriented actions may be considered, such as improving training, modifying work procedures and policies, transferring employees, or recommending dismissals.

When correcting performance, a manager should offer negative feedback without attacking the employee's self-esteem. Feedback must be focused on results and outcome—not the person—and directed toward the future, without upsetting employees or harboring punitive motives. Managers should demonstrate a helpful and sincere attitude and pose no threat to their workers (*Harvard Business Review* 2014).

Generally speaking, it is not good for employees to make mistakes in the fundamentals of engineering. It is acceptable to fail in new and risky development projects, but making the same mistakes again and again is viewed negatively by all management.

5.7 Means of Control

There are a number of tools available for managers to exercise control, such as performing personal inspections, reviewing current progress, and defining any deviation from plans. This is the strategy of control by way of focusing on exceptions. Managers may also set priorities with respect to job assignment, resource deployment, and technology application. This is exercising control by managing resources (Storey 2014).

5.8 General Comments

Managers must constantly define which tasks should be performed and have employees perform these tasks correctly. The principle of the critical few (the Pareto principle) states that, as a rule, 20% of factors may affect 80% of outcome (see Figure 5.1). The key is, of course, for managers to properly define these critical few, allocate resources to pursue them, and achieve the desirable outcome.

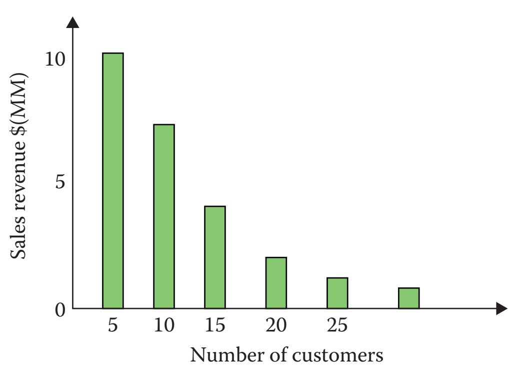

FIGURE 5.1
Pareto principle.

Control should be focused on where action takes place. In general, self-control imposed by the workers involved is the most effective type. However, by and large, people also resent control, and extensive control may lead to loss of motivation. Therefore, managers must manage both positive and negative exceptions. With information available and mechanisms in place, the preferred type of control is flexible and coordinated.

5.9 Control of Management Time

Time is a valuable and limited resource for everyone, including managers. Management tasks have several common characteristics: important tasks often arrive at unpredictable times, trivial tasks often take up a disproportionately large amount of time, and interruptions are common to a manager's schedule.

Some managers may waste a lot of time if the roles and responsibilities of their employees are not clearly defined. Often, a lack of self-discipline—procrastination, confused priorities, lack of personal drive, or lack of planning—wastes time. Other managers suffer from a lack of effective delegation; for example, there may be a delegation of responsibilities without the commensurate authority, or the application of too little or too much control. Still other managers waste time because of poor communication related to policies, procedures, meetings, and other subjects (Cockerell 2015). The following techniques may help managers avoid wasting time:

1. Set goals for the day, the week, the month, and the year.
2. Prioritize tasks to be done, beginning with the most important tasks (A tasks), then doing the less important ones (B tasks), and leaving the least important ones (C tasks) untouched if time is insufficient. Make sure that the tasks are relevant and add value. Reserve blocks of time to pursue A tasks.
3. Plan each task beforehand and group some of them together.
4. Minimize interruptions by keeping the office door closed for a specific time period and asking the secretary to hold all phone calls.
5. Make use of waiting time at the airport, on the train, in the doctor's office, and so on.
6. Keep reports and memoranda short and to the point. Some managers in industry have the habit of browsing over only the first page of any report and stopping if the information is uninteresting, of secondary importance, or irrelevant to their current needs.

Enumerated in Table 5.3 are some time-saving tips that are adopted from several published sources (Glei 2013; Reese 2014; Smith 2014; Goldman 2014). Engineering managers may find them useful.

Example 5.3

The customer service manager is a busy person. He rushes from one problem to another without actually taking time to complete any job or solve any problem properly.

What control problem does the customer service manager have? What can he do to enhance his job effectiveness?

Answer 5.3

The customer service manager has a time-control problem. He reacts to problems and does not discharge his job responsibilities effectively. He can do several things to rectify the situation:

1. Organize the customer service department into groups (e.g., repairs, parts supply, warranty, problem solving by phone) and know the capabilities of his support staff for these groups of services.
2. Set up the call center operation to automatically channel customer calls to the respective service groups.
3. Delegate the responsibilities of providing customer services to the leaders of these groups, requiring them to follow through on each and every one of the customer problems and keeping good records of all services rendered.
4. Refer specific problems (e.g., nasty customers) that the group leaders cannot resolve for the customer service manager to handle personally.
5. Assign the analysis of service records to someone who can apply statistics and define trends suggested by these data (e.g., parts with highest failure rate, nature of frequent complaints, average time spent on problem solving, number of calls from customers unhappy with company's services).
6. Establish a system to solicit customer feedback on service and suggestions for improvement.
7. Set up metrics to measure service quality (e.g., number of complaints per week, average service time spent per customer, cost per service call), making use of best practices available in the industry.
8. Monitor progress and seek ways to constantly improve the service operation.

TABLE 5.3

Time-Saving Tips for Managers

1. Set goals	Write specific, measurable outcomes that you want to achieve in the next week, month, year, and five years. Consider your work, relationships, play, and well-being. Progress from goals to plan to work.
2. Use a master "to-do" list	Categorize all "to-do" ideas according to which goal each serves. Estimate all others.
3. Get the big picture	Plan your priorities so that you work foremost on whatever gives the biggest payoff and potential.
4. Cluster common tasks	Do similar tasks in the same time block (e.g., a batch of letters, several phone calls).
5. Create systems	Keep tools, forms, checklists, and information handy and organized for repetitive tasks.
6. Establish place habit	Keep everything in its predetermined place.
7. Delineate time blocks	Schedule blocks of uninterruptible time (two to four hours) to work on projects requiring concentration. Assure colleagues of availability otherwise.
8. Design your environment	Make your setting conducive to concentration (e.g., sit with your back to traffic passing your office and screen calls).
9. Cut meeting time	Use proven meeting time savers (e.g., go to others' offices for meetings, do stand-up meetings, set an agenda and follow through rigorously).
10. Lessen panic	Handle what worries you the most. Ask yourself, "Will this matter seem urgent 10 years from now?"
11. Take the one-minute test	Periodically take a minute to ponder, "Am I doing this in the best way to meet my goals, serve others, and take care of myself?"

Source: Condensed and adopted from Cottringer (2003), Casavant (2003), and Anonymous (2003).

5.10 Control of Personnel

Managerial control is exercised primarily for the purposes of maximizing company productivity and minimizing potential damages arising from an ineffective use of company resources, as well as problems related to ethics, laws, safety, and health issues. For highly skilled personnel, such as science, technology, engineering, and math (STEM) professionals, less control is usually more effective and acceptable. Excess control induces undesirable reactions and produces adverse effects. This is best illustrated by the supervision curve displayed in Figure 5.2.

To manage creative people, or those who are able to produce new and useful results, managers need to set targets, monitor the employees periodically, apply a low level of supervision, and maintain a collaborative and creativity-inducing work environment (Mathis et al. 2013).

Example 5.4

Mary Stevenson, the shop manager, works well with all of her staff members. She relies on Mike Denver, who has the longest tenure and most extensive experience in the group, as the second in command for day-to-day operations. The shop is modernizing its operation with the use of computers. Mary Stevenson and her boss, Craig Martin, decide to bring in a young computer specialist, Janet Carter, from the outside.

To make sure that the shop modernization process moves forward, Mary Stevenson spends a lot of time with Janet Carter. Mike Denver sees less and less of Mary Stevenson, although Mary still depends on Mike for day-to-day operations. Mike resents being shut out from the work done by Mary and Janet. Mike does not complain, but after six months, he tenders his resignation and goes to work for a competitor. Mary Stevenson is shattered. She deeply regrets this major loss to the shop.

What went wrong? What was not controlled? What would you do differently?

Answer 5.4

The key issue at hand is that Mike perceived a loss of trust and respect from Mary. Mike also incorrectly perceived his own approaching obsolescence resulting from the shop's computer technology. Both of these misperceptions caused Mike to have serious doubts about his future personal standing in the shop. Mary did not anticipate these perceptions and misunderstandings and did nothing to correct them in a timely manner.

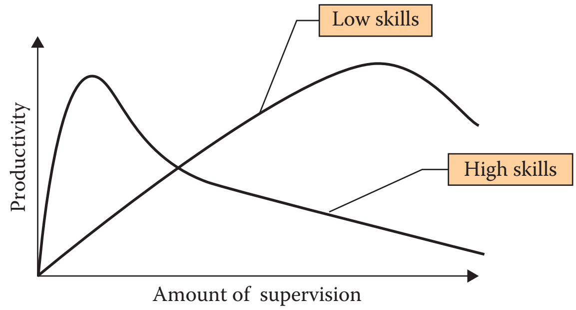

FIGURE 5.2
Supervision curve.

Mary Stevenson should have done the following:

1. Bring Mike Carter into the loop of hiring a computer specialist to broaden the skill sets of the shop. Allow Mike to participate in the selection and interview process.
2. Announce in a staff meeting that Mary needs to spend time to bring Janet along initially and that Mike will actively assist in taking care of day-to-day operations in the shop.
3. Get Mike involved in the work done by Janet, so that Mike, as the second in command, is kept up to date with this new type of computer work planned for the shop. Should Mike need to take over the management of the shop at some future time, he would have been given time to familiarize himself with the new computer-related operation. Grooming a candidate in the shop for possible succession in the future should have been Mary's responsibility anyway.
4. Maintain a balance of management attention to both computer-related and other tasks in the shop.

5.11 Control of Business Relationships

As industrial markets become increasingly global, business relationships (defined by whom the company knows and how well) represent an increasingly important competitive force in the marketplace (Hoffman et al. 2014).

It is highly advisable that managers acquire the habit of proactively forming, maintaining, and controlling new business relationships for the benefit of their employers and themselves.

Contacts may be established with noncompetitors. At proper occasions, such as professional meetings, technical conferences, seminars, and industrial exhibitions, managers should be accustomed to introduce themselves to others with a five-second "commercial"—a brief self-description of their key areas of expertise. They should take note of others' professional specialty areas and follow up with periodical exchanges to nurture the relationships. Over time, such a network of professional contacts may become a very powerful business asset to managers and their employers (Menken 2011).

5.12 Control of Projects

Managers exercise control over projects when serving as project leaders (Kerzner 2014). Tools for project control include program evaluation review technique (PERT), critical path method (CPM) charts, or suitable computer or Internet-based project management software (see Section 12.3.2). Project control focuses on several key issues, as indicated in Table 5.4.

To manage and control projects, STEM professionals need skills related to organizing and planning, people management, problem solving, communication, change management, and checking on technical and financial feasibility. They also need to have drive and energy, broad technical knowledge, and an optimistic outlook, and to be goal-oriented and customer focused.

TABLE 5.4

Project Control Issues

1. Cost control	Monitor the actual versus projected percentage of cost expenditures and take proper actions to minimize deviations.
2. Schedule control	Monitor the actual versus projected percentage of completion time and take the proper actions to minimize deviations.
3. Critical path activities	These are activities without time slacks, which must be managed with extra care to avoid schedule delay.
4. Task deviation from plan	Delays arise from slow equipment delivery or installation; equipment damage in transportation; construction delay due to labor action, weather, utilities, and other causes; and changes of personnel.
5. Collaboration	Securing collaboration among team members is a key success factor for any project.
6. Technical and financial feasibility	Make sure that the project can be technically implemented and that the expected financial value justifies the expected cost of the project.
7. Conflict resolution	Resolving instantly all conflicts and problems among team members will ensure a smooth progress toward achieving the project goals.

5.13 Control of Quality

To achieve success in the marketplace, companies must focus on the quality of products/services they offer. Thus, the planning and implementation of quality control programs represents a major corporate undertaking for all progressive companies (Adams 2012).

In the automotive industries, product quality is a well-recognized competitive factor. A recent study by J. D. Power Associates in 2014 indicates that Porsche, Jaguar, Lexus, Hyundai, and Toyota are the top-five carmakers, with fewer problems per 100 vehicles than the industrial average of 116 problems, ahead of Chevrolet, BMW, Lincoln, Chrysler, Cadillac, and Ford. The metric of the industrial average number of problems per 100 vehicles has been decreasing steadily for some years now.

Many years ago, Deming (2000) promoted the concept of product quality in the United States but attracted few followers. He went to Japan and was enthusiastically welcomed there. Since then, a number of quality control practices have been created by the Japanese, such as quality circles, Kaizen, Kanban, just in time (JIT), Lean production, Taguchi, Ishikawa, and the 5S campaign. Kanban means looking up to the board in order to adjust to a constantly varying production schedule. The 5S campaign includes (1) seiri—arrangement, (2) seiton—tidying up, (3) seisou—cleaning, (4) seiketsu—cleanliness, and (5) shukan—customizing (Taylor 2013).

Kaizen means "change for the better." It includes a number of quality practices, such as customer orientation, total quality control, robotics, quality circles, suggestion system, quality betterment, JIT, zero defects, small group activities, productivity furtherance, and corporate labor–management relationships. Kaizen begins and ends with people. An involved leadership guides workers to strive for lower cost, higher quality, and faster delivery of goods and services to customers (Kelly 2015; Miller et al. 2013). The elimination of all non-value-adding activities is a key emphasis in the Kaizen approach. Table 5.5 presents numerous sample Kaizen steps taken by various manufacturers. Many of these steps are based on common sense.

These quality concepts are logical, reasonable, practical, and, above all, obvious. In fact, there is really nothing new or novel in them. Many of these quality concepts were

TABLE 5.5

Sample Kaizen Steps

No.	Sample Kaizen Steps
1.	Get the most useful ideas to improve operations from the workers involved.
2.	Conduct time studies and observe the actual work activities to evaluate productivity.
3.	Use questionnaires to collect data and small group discussions to encourage worker participation.
4.	Workers should put everything they need next to them to minimize time (JIT and Lean production).
5.	Use a checklist that is constantly revised to inspect and study the shop floor activities.
6.	Combine several process steps to lessen efforts required saves resources.
7.	Incorporate prefabricated component modules to cut cost.
8.	Use lighter and more versatile manufacturing equipment to whittle away manpower and utility costs.
9.	Use flexible welding jigs and general purpose pallets to cut welding costs.
10.	Use electric-driven robots and adopt a new server gut welder to increase spot welding speed.
11.	Use general purpose carriers with common pickup points to handle all car models.
12.	Combine primer and top coats in a single operation to gain 15% in speed and cut down energy consumption based on the use of a resin (a polyacetal), which would rise from the primer coat to the surface and separate the primer from the top coats.
13.	Decrease the number of seat sets and apply more common components in design.
14.	Use a combination of automatic, semiautomatic, and small lot stations to make products of different models and volumes.

subsequently "reimported" to the United States with Japanese labels. Thereafter, American managers started paying attention to quality.

Knowing what to do is useful, but it is not enough. Pronouncing a few quality terms in Japanese will impress no one. Practicing the quality concept meticulously is the only key to success in quality enhancement and control. To achieve useful results in quality, management commitment is essential. Management commitment is reflected in company value, vision, resources assignment, customer focus, long-term strategic orientation, and rewards systems in place. In addition, worker dedication—drive to excellence, attention to details, and continuous betterment—must be assured.

It is interesting to note that, during the last 20-plus years, foreign automakers opened a total of 17 factories in the United States to produce cars, using American workers. Their superior product quality output can only be attributed to superior management practices, as there is no difference in culture, language, or value systems between American workers employed by General Motors or Ford and those working in U.S. factories for Toyota, Nissan, or other foreign carmakers. Maynard (2004) pointed out that General Motors had 60% of the American car market in 1960 and has only about half of that today. The share of the light-vehicle market owned by foreigners is now already 40%. Toyota is predicted to overtake General Motors and become the largest car company in the world in the near future. Maynard further pointed out that there is a difference in the backgrounds of the lead managers involved. General Motors and Ford have been headed by financial professionals, whereas Toyota, Volkswagen, BMW, and Mercedes are led by engineers who are "passionately interested in everything to do with cars." This could be a factor affecting the varying extent of management commitment devoted to product quality.

Another case in point is the implementation of the quality program. Ford Motors Company is credited for having spearheaded the well-known failure mode and effect analysis (FMEA) method in the U.S. automotive industry around 1977 (Carlson 2012).

TABLE 5.6

FMEA Worksheet

1.	Step number
2.	Process description
3.	Potential failure mode
4.	Potential effects of failure
5.	Severity
6.	Potential causes of failure
7.	Occurrence
8.	Current process control and detection
9.	Detection
10.	Risk response number (RPN)
11.	Recommended actions
12.	Responsibility and target completion date
13.	Actions taken
14.	New severity
15.	New occurrence
16.	New detection

FMEA may be applied to design, process, service, and other engineering or business activities that may go wrong. Murphy's law says, "If something can go wrong, it will." FMEA is a proactive program intended to catch all possible failure modes before they actually occur. It is solidly based on the understanding that the correction of potential failures before they actually occur will be much less costly than the required remedial actions after the fact.

The FMEA concept is rather straightforward. Table 5.6 includes the headings of an FMEA worksheet. For a given step number, the process description, potential failure mode, and potential effects of the failure in question are to be entered. Then, the severity factor (Row E) is assessed, using a number between 1 and 10 (10 being the most severe), regarding the impact on customers. Row F registers the potential root cause for the failure. Row G defines the probability of its occurrence, again using a number between 1 and 10, with 10 being the most likely to occur. Row H specifies the current control and detection practices. The detection factor (Row I) is assigned a value between 1 and 10, with 10 being the most difficult to detect (Stamatis 2014).

The factor RPN (risk response number, Row J) is the product of three numbers: severity (Row E), occurrence (Row G), and detection (Row I). Remedial or preventive actions (Row K) are to be taken according to the priority order based on the RPN. Row L tabulates the person responsible for taking the recommended actions. Row M documents what actions were in fact taken.

Rows N, O, and P contain the results of reevaluation of the failure mode in question after remedial and preventive actions have been undertaken. The new post-action RPN number is expected to be significantly lower than its corresponding preaction number, and it documents the corrective impact on the failure mode. Such documents may be used to satisfy the customer's requirements and serve as guidelines to drive continuous improvement.

Applying FMEA systematically should lead to a continuous reduction of the effects of failure modes in product design, product manufacturing, service, and other engineering or business applications. Many U.S. automotive companies and their tiered suppliers have applied FMEA with varying degrees of success. Although Ford initiated the use of FMEA back in 1977, it still lags behind other industrial leaders today in terms of problems per 100 vehicles (Ford was identified as having 116 problems versus Porsche's 74 problems by the J. D. Power Associates 2014 study). This drives home the point that having knowledge about quality is useful, but implementing quality control steps represents the key step in achieving quality performance. Successful implementation requires management commitment and worker dedication. Technically, FMEA can be successfully implemented. The management challenge is how to achieve better quality performance consistently for all nameplates or products, and over a long period of time.

Like Kaizen and FMEA, TQM is also a very powerful program addressing the issues related to product quality and organizational productivity (ASQ Quality Press 2013). In a typical academic course at the graduate level, TQM covers the concepts of customer satisfaction, empowerment of employees in problem solving, continuous improvement, and management excellence by creating and implementing corporate visions. To achieve TQM success, management commitment and worker dedication are also required.

Quality control is an important function, in which managers play a key role. They need to be actively and persistently involved with workers to apply common sense in eliminating wastes, speeding delivery, simplifying processes, paying attention to the gritty details of practice, and continuously improving the way work gets done.

Example 5.5

What is the generic problem-solving approach applicable to solve most engineering and management problems?

Answer 5.5

The generic problem-solving approach may look like the following (Fogler et al. 2013):

1. Perform a situation analysis (e.g., assess strengths, weaknesses, opportunities, and threats).
2. Formulate a statement of the problem.
3. Define performance standards that are observable, measurable, and relevant to the goal.
4. Generate alternative solutions to the problem.
5. Evaluate these alternatives in terms of their consequences to the organization.
6. Select the best alternative solution with the highest value and the lowest adverse effect on the organization.
7. Implement a pilot test of the proposed solution and revise as indicated by practical experience.
8. Implement the solution.
9. Evaluate the outcome.
10. Revise the process as necessary.

Note that there is no one universal solution to all management problems, but that the correct solution will depend on the unique needs of the situation.

The problem-solving process practiced by Xerox Corporation is a good example of the approaches taken by many companies in industry (Garvin 1993). The Xerox problem-solving process contains the details shown in Table 5.7.

TABLE 5.7

Xerox's Problem-Solving Process

Step	Questions to Be Answered	Expansion/ Divergence	Contraction/ Convergence	What Is Needed to Go to the Next Step
1. Identify and select the problems.	What do we want to change?	Multiple problems for consideration.	One problem statement, one "desired state" agreed on.	Identification of the gap and description of the "desired state" in observable terms.
2. Analyze problems.	What's preventing us from reaching the "desired state"?	Multiple potential causes identified.	Key cause(s) identified and verified.	Key cause(s) documented and ranked.
3. Generate potential solutions.	How could we make the change?	Multiple ideas on how to solve the problem.	Potential solutions clarified.	Solution list.
4. Select and plan the solution.	What's the best way to do it?	Multiple criteria for evaluating potential solutions. Multiple ideas on how to implement and evaluate the selected solutions.	Criteria to use for evaluating solutions agreed on. Implementation and evaluation plans agreed on.	Plan for making and monitoring the change. Measurement criteria to evaluate solution effectiveness.
5. Implement the solution.	Are we following the plan?		Implementation of agreed-on contingency plans (if necessary).	Solution in place.
6. Evaluate the solution.	How well did it work?		Effectiveness of solution agreed on. Continuing problems (if any) identified.	Verification that the problem is solved, or agreement to address continuing problems.

5.14 Control of Knowledge

Knowledge refers to the sum total of corporate intellectual property, which is composed of patents, proprietary know-how, technical expertise, design procedures, empirical problem-solving heuristics, process operational insights, and others (North and Kumta 2014; Leonard et al. 2014). Some of these knowledge chunks are documentable, while others typically reside in the employees' heads.

Managers are generally responsible for developing, preserving, safeguarding, and applying corporate engineering and technology knowledge. They also need to develop policies to facilitate the control of such knowledge. Some examples of knowledge management strategies are listed in Table 5.8.

One of the major difficulties in knowledge management is that many knowledge chunks are dispersed throughout various documents within the company. Data mining software products represent new tools to help extract and group together related information from

TABLE 5.8

Knowledge Management

1. Experimentation	Put systems and processes in place to facilitate the search for and testing of new knowledge.
2. Benchmarking	Learn from one's own experience, and best practices of others in industry, by reflection and analysis.
3. Preserve knowledge	Set policies concerning the preparation of reports, design procedures, and data books. Apply knowledge acquisition tools to preserve valuable heuristic knowledge.
4. Dissemination of knowledge	Rotate experts to different locations or jobs so that knowledge may be shared with and learned by others. Make knowledge or data available electronically companywide.

diverse sources for wide dissemination and effective use by others. Another major difficulty in managing knowledge is that most domain experts do not like to share their knowledge with others, rendering the use of knowledge acquisition tools somewhat ineffective.

Knowledge control is particularly important from the viewpoint of countering industrial espionage. Special policies regulating employee contact with competitors at neutral sites (such as professional meetings, university environments, and industrial seminars) need to be defined to safeguard company knowledge.

Preserved or acquired knowledge adds little value to the company if there is no resulting refinement or improvement in the way work gets done. Managers also need to focus on effectively transferring the knowledge gained to achieve a modification of the company's behavior that uses the new knowledge and insights. Doing so will make the company a true learning organization that steadily enriches itself.

5.15 Conclusion

Control is another important function of engineering management, which focuses mostly on the administrative and operational aspects of the work. Control is essential to the implementation of any project or program activities by specifying performance metrics, motoring progress for initiating corrective steps, and ensuring the attainment of useful outcomes.

Particular attention should be paid to external benchmarking when setting standards in order to avoid causing a company to lose its long-term competitive strengths. Delegation without proper control will likely result in wasting the company's resources (e.g., time, manpower, know-how, and management attention).

Control is routinely applied to team members, knowledge, business relationships, and the allocation of resources, as they all contribute directly to the specific project objectives at hand. Care must be taken in dealing with professionals, who generally prefer to be guided by specific objectives and then empowered to select the right course of action to achieve the project objective within the given time and budget constraints. On the one hand, tight and rigid control discourages employee initiative. On the other hand, too loose a control could lead to the project objectives being missed. Exercising the right level of control is of critical importance, dependent on the people, the nature of the project, its urgency and impact, and the risks entailed.

As a general rule, setting clear and understandable standards and performance goals and insisting on good planning efforts will encourage employees to exercise self-directed control while promoting participation, involvement, and employee motivation.

QUESTIONS

1. A number of years ago, ISO Standards 9000 series were developed to promote work quality by standardizing engineering design, testing, production, and other procedures. How many ISO standards are there, and how well have these standards been accepted in the United States?
2. A company decides to offer an average annual raise of 8%, although the current inflation rate is 10%. Each engineering manager decides on the best way to distribute the salary increases to his or her staff. However, if everyone gets an increase of 8%, there will be no differentiation between strong and weak performers for the previous year. What should you do as an engineering manager?
3. A key engineer in the department hands in her resignation notice; her reason for leaving is that she has been offered a much higher salary by a competitor. The manager recommends to the director that the company match the competitor's offer, even though this would allow the engineer to earn above the maximum for her grade. "We can always give her smaller increases in subsequent years to bring her salary back into line," says the manager. What should the director do?
4. Motivation in the assembly shop is high. However, the shop manager notices that, although the daily production is above average for the shop, it drops down to a low during the first hour after the lunch break. It is further diagnosed that the operators tend to continue socializing till well after the lunch break.

   The shop manager changes the lunch break and staggers it over a two hour period so that the operators cannot go to lunch together. To his surprise, motivation begins to fall, and productivity drops dramatically.

   What do you think is the problem? How do you advise the shop manager to fix this problem?
5. Bill Carter is an excellent hardware designer, but he wants to move into management to broaden his experience. His manager is supportive and encourages Bill to go to evening classes on management. Bill works hard for two years and graduates first in his class. Soon, there is a management opening in the procurement department. Bill applies for it, but an outside applicant eventually fills the position. Bill is turned down because he does not have sufficient experience in the procurement functions, a stated key requirement for the job.

   Bill protests, "But I have better technical knowledge of components than all the procurement engineers put together, and I learned about procurement in my management courses. The only way I will get experience is to work on the job."

   Do you think Bill should have been given the job? How would you have handled this situation differently?
6. The company president has noted a constant increase in the number of reports passed on to her, many of them coming through the mail, some through the company's intranet. Most of these reports remain unread, although, when traveling for business, the company president does find time to browse through some of the

reports while on the airplane. It has clearly become difficult for her to keep track of all projects due to information overload. However, she does not want to abandon her personal objective of being constantly informed, and she does not want to query her vice presidents for summaries of major developments.

What are the alternatives available to the company president?

7. The production department is undergoing an upgrade of its automation program. It has a conflict that needs to be controlled and managed. The line supervisor wants to standardize on machines supplied by an American vendor, as his people will eventually use them. The automation team leader believes, on the other hand, that Swiss-made machines will result in greater productivity. Being a specialist in automation, she was brought into the department to find ways of significantly improving productivity.

   The department head does not know what to do, as these two experts frequently fight in staff meetings. He regrets that he has not kept up with the automation technology to enable him to arbitrate and decide on the best way.

   What should the department head do now?

8. Two junior members of the production department unexpectedly come in to see you, the production director, to complain that their manager, who reports to you, commits discrimination, practices favoritism, and misuses company facilities for possible personal gain.

   How would you handle this complaint?

9. At present, the company is running at full capacity in developing a new product for a major customer. The sales director has unexpectedly secured a small, but highly profitable, order, which requires some low-level development work and a minor change to the current production process.

   Should the company accept the small order? If so, how should the company satisfy the small order?

10. Some foreign countries, particularly those in the early stages of industrial development, are known to illegally copy product designs and technologies that originated from developed countries.

    What are the best ways for small businesses to protect their technical know-how in foreign countries?

11. John Elrod founded the Elrod Manufacturing Company 50 years ago. Vernon Scott is the vice president of plant engineering, reporting to George Elrod, who took over as the company president from his father, John, five years ago. Vernon Scott and John Elrod have been good friends for many years. The company's products include automotive parts (such as gears, axles, and transmissions), metal stampings, and sheet metal subassemblies.

    Also reporting to George Elrod are six plant managers. Each plant has its sales, engineering, manufacturing, warehouse, and other functions. The plant managers are responsible for the profitability of the individual plants. The total employment of the company is 12,000 people.

    The company has a standing policy on capital expenditure: expenditures below \$5,000 are to be approved by plant managers, those between \$5,000 and \$50,000 by Vernon Scott, and those above \$50,000 by the executive committee.

Vernon Scott favors expenditures for machinery and equipment directly related to manufacturing, but not for maintenance, facility expansion, or improvements that are not related to manufacturing. Over the years, plant managers have become unhappy with Scott's refusal of expenditures for nonmanufacturing equipment, such as computers. Forced to keep their plants profitable, they cannot help but bypass him by breaking down the nonmanufacturing projects into many small components, each below $5000.

Eventually, Vernon Scott finds out about the piecemeal purchase of a $27,000 computer by Paul Nelson, a very capable plant manager whose plant has become the most profitable in the company. Scott demands that George Elrod fire Nelson, citing insubordination, cheating, and dishonesty.

What would you do if you were George Elrod?

12. The manufacturing manager of Company X had installed a wage incentive program. She happily reported six months later that the system was a success because production was up and unit costs were down. A quality control manager said, however, that the percentage of rejects had increased markedly and that this was creating a backlog of rework requirements. An industrial engineering manager reported that the expenditures for industrial engineering studies in the department were up by 50%. An industrial relations manager said that arbitration fees resulting from incentive grievances had tripled.

    Discuss your observations in this case. What should be done to correct the situation in this production department?

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Section II

Business Essentials for Engineering Managers

Section II covers the fundamentals of business, including cost accounting (Chapter 6), financial accounting and management (Chapter 7), and marketing management (Chapter 8). This section is to enable science, technology, engineering, and math (STEM) professionals and managers to facilitate their interactions within peer groups and units and to acquire a broadened perspective of the company business and its stakeholders.

Section II also prepares STEM professionals and managers to make decisions related to cost, finance, product, service, and capital budgets—discounted cash flow and internal rate of return analyses are reviewed. These discussions are of critical importance, as decisions made during the product design phase typically determine up to 85% of the final costs of products. Activity-based costing (ABC) is presented to define indirect costs related to products and services. Economic value added (EVA) is addressed, which determines the real profitability of an enterprise above and beyond the cost of capital deployed.

Also discussed are capital formation through equity and debt financing, resource allocation concepts for assets in place, and option pricing for capital investment opportunities. By understanding the project evaluation criteria and the tools of financial analyses, STEM professionals and managers will be in a better position to secure project approvals. A critical step to developing technological projects is the acquisition and incorporation of customer feedback. For STEM professionals and managers to lead, a major challenge is the initiation, development, and implementation of major technological projects that contribute to the long-term profitability of the company.

The important roles and responsibilities of marketing in any profit-seeking enterprise are then introduced, along with the contributions expected of STEM professionals and managers to support the marketing effort. Many progressive enterprises are increasingly concentrating on customer relationship management to grow their businesses. Such a customer orientation is expected to continue to serve as a key driving force for product design, project management, plant operation, manufacturing, customer service, and many other engineering-centered activities.

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6

Cost Accounting for Engineering Managers

6.1 Introduction

Cost control is a very important management function in both profit-seeking and nonprofit organizations.

A profit-seeking organization strives to maximize its financial gains (e.g., sales revenue minus costs) for its owners. These gains can be sustained over time only if all stakeholders of the firm (e.g., stockholders, customers, employees, suppliers, business partners, and the community in which the firm operates) are reasonably satisfied. A nonprofit organization (e.g., the United Way, the Ford Foundation, government agencies, educational institutions, and church organizations) seeks to maximize its service value to its respective target recipients while minimizing operations costs.

This chapter covers the basics of cost accounting. The discussions focus on the costing of products, although all cost accounting concepts are equally applicable to the costing of services (Vanderbeck and Mitchell 2015; Horngren et al. 2014; Bragg 2014). First, some commonly utilized accounting terms are introduced. Then, the cost analysis of a single period versus multiple periods is explained, leading to topics such as the time value of money and compound interest formulas. The costing of products follows, including the estimation of direct costs absorbed into the company's inventory. The complex problem of assigning indirect costs to product/services is illustrated by the conventional method of using overhead rates, as well as by the more sophisticated method of activity-based costing.

Estimation of costs with uncertainties is then presented. The Monte Carlo simulation is introduced as an effective method to account for cost uncertainties. Its superiority over the conventional estimation method, which uses deterministic data, is clearly demonstrated through examples of the output distribution functions of the Monte Carlo simulation. Finally, inventory accounting is addressed to arrive at the all-important cost of goods sold (CGS).

It is important for all engineering managers to become well versed in cost accounting. Cost control is a basic management task actively performed by all technology-based organizations, such as manufacturing, engineering, construction, product development, product design, technology applications, and services.

6.2 Product or Service Costing

Product or service costing is one of the key responsibilities of managers, as the accurate computation of the CGS is of paramount importance to a product- or service-centered company (Ryan and Starmanns 2015).

6.2.1 Cost of Goods Sold

Product costing in a product-centered company requires the computation of costs related to direct material (DM), direct labor (DL), and factory overhead (FO) for the following three operations:

- Raw materials (Stores)
- Work in progress (WIP)
- Finished goods (FG)

The following additional definitions are helpful:

Prime cost = DM + DL

Conversion cost = DL + FO

Indirect manufacturing cost = FO, also called factory burden. FO includes all costs other than DM and DL.

Typically, *T-accounts* are set up for the Stores, WIP, and FG operations.

A T-account is a tool used commonly by accountants to record transactions. As a convention, an increase in assets (e.g., cash, accounts receivables, inventories, land, and machines) is debited to the left side of the T-account. A decrease in assets is credited to the right side of the T-account. The opposite is true for liabilities and owners' equities. For additional discussions on the use of T-accounts, see Section 7.10.1.

The following schematic diagram illustrates product costing:

Stores		WIP		FG	
Debit	Credit	Debit	Credit	Debit	Credit
(1)	(2)	(3)	(4)	(5)	(6)

Explanations:

1. Purchasing raw materials (an increase in assets).
2. Putting materials into a production process (a reduction in stores assets).
3. Production is initiated, adding value to raw materials, while consuming labor, materials, utilities, and other resources (assets are increased).
4. Production is complete and units shipped out to FG operations (a reduction of WIP assets).
5. Receiving of FG in storage (an increase of FG assets).
6. FG are shipped out for sale (a reduction of FG assets).

Note that in the product costing schematic diagram, materials flow from left to right, whereas cash (financial resource) flows from right to left. The following illustrates a specific example of product costing:

Stores		WIP		FG	
Debit	Credit	Debit	Credit	Debit	Credit
Beg. 75	3[b]	Beg. 22	440[f]	Beg. 50	
198[a]	187[c]	125[d]		40[f]	430[g]
		147[e]			
		187[c]			
End. 83[h]		End. 41[h]		End. 60[h]	

[a] Purchased material for $198.00.
[b] Received credit for having returned the material purchased.
[c] DM actually shipped to WIP and used in the accounting period.
[d] DL used and cost assigned.
[e] FO used and cost assigned.
[f] Product completed and transferred out (cost of goods manufactured).
[g] FG shipped out to customer, receiving the CGS as credit.
[h] The sum of ending balances in Stores, WIP, and FG represents inventory at the end of the accounting period.

In computing the CGS, the inclusion of materials and labor costs is rather straightforward, as these are direct costs, which are quite easy to track. The difficulty in product costing is the inclusion of indirect costs, namely the FO, as in the specific example illustrated. For manufacturing operations in which the FO represents a small fraction of the total product cost, the precision with which to allocate the indirect costs is practically irrelevant. However, in other circumstances, the allocation of indirect costs must be precise, especially when the FO becomes a major portion of the product cost and the plant facility generates multiple products.

6.2.2 Traditional Method of Allocating Indirect Costs

The traditional practice of general ledger costing involves estimating all overhead costs for the upcoming year in a single cost pool (e.g., FO, utilities, safety program, training, and salaries of foremen and factory managers). This total is then divided by the estimated number of labor hours to be worked. The result is an hourly overhead rate. For each product, the required labor hours are estimated. The total overhead cost for the product is then equal to the required labor hours multiplied by the hourly overhead rate.

For example, let us assume that a factory has $800,000 in overhead (e.g., salary of manager, benefits, and other general charges), 2,000 direct hours per employee per year, and 20 employees. The hourly overhead rate is then $20 per hour (= 800,000/(2,000 × 20)).

The major deficiency of this method of allocating indirect costs is that it does not reflect the true relationship between the indirect costs and the applicable cost object (such as products, services, and customers). Therefore, the allocation is often improper, as diverse types of overhead costs are lumped together, making an in-depth analysis impossible (Cooper and Kaplan 1988).

A better method of allocating indirect costs is *activity-based costing* (ABC), which is introduced next.

6.2.3 Activity-Based Costing

ABC is a cost accounting technique by which indirect and administrative support costs are traced to activities and processes and then to the cost objects (e.g., products, services, and customers) (Hicks 2002).

ABC is built on the notion that an organization has to perform certain activities in order to generate products and services. These activities cost money. The cost of each of these activities is only measured by and assigned to those products or services requiring identifiable activities and using appropriate assignment bases (called *cost drivers*). The results of ABC analyses offer a relatively more accurate picture of the real cost of each product or service, including the cost of serving customers. Nonactivity costs (such as DM, DL, or direct outside services) do not need to be included because these costs are readily attributable to the specific product or service under consideration.

ABC is most useful for companies with diverse products, service centers, channels, and customers, and for those companies whose overhead costs represent a large percentage of their overall product and service costs (Maingi 2013; Moore 2012).

All managers should learn to practice ABC, because the traditional method of allocating overhead uses only high-level information about costs, and the general ledger system does not provide information related to time and resources spent on assignments and activities. In contrast, a well-practiced ABC method offers specific insights that include (a) a clearer picture for management of what generates profits and losses for the company; (b) the ability to track operating profits for specific cost objects (such as customers, orders, and products); (c) the ability to determine whether a service center is efficient or deficient; and (d) the possibility of identifying the relative profitability among µproducts and customers.

A company may lose money on some products, orders, and customers even with an overall documentable profitability, when the financial data are hidden in the absence of ABC. According to the published best practices of some industrial pioneers (such as Honeywell Inc. and Coca-Cola®) on the use of ABC, simpler ABC models deliver better results.

ABC has become increasingly popular with industrial companies, partly because it is useful for organizations of any size and does not require a massive effort to implement, and partly because of increased processing capabilities of personal computers (PCs), reduced prices for ABC software products, and increased competition forcing companies to achieve a better understanding of their own product costs. ABC software for Microsoft Excel is marketed by MrDashboard.com. There are also comprehensive ABC management tools on the market. Examples include: (1) Profitability and Cost Management (PCM) by SAP, (2) Hyperion Profitability and Cost Management (HPCM) by Oracle, and (3) SAP Activity-Based Cost Management by SAP.

6.2.4 Sequential Steps to Implementation of ABC

It is advisable to form a cross-functional team when implementing the ABC method of allocating indirect costs. The team should determine the cost objects. Examples of cost objects include costs to serve customer; costs to purchase, carry, and process products; costs to order, receive, sell, and deliver products; and costs to perform other activities. (Cokins 2001).

The team then needs to define activities that represent homogeneous groups of work (such as accounting, machining, forging, and design), which add value to the cost objects.

TABLE 6.1

Cost Drivers

Activity	Cost Driver
Loading	Tons
Driving	Miles
Invoice processing	Number of invoices
Machining	Machining hours
Material movement	Weight
Production	Number of products

Next to be determined are cost drivers. These are the agents that cause costs to be incurred in the activities, which in turn exert a direct impact on the cost of a given cost object. Examples of cost drivers are shown in Table 6.1.

The next step is to attribute activity costs to cost objects. The use of a flowchart for modeling the process is recommended. The resulting information generated by ABC is useful as a basis for new management decisions.

6.2.5 Practical Tips for Performing ABC

When management initiates the process of creating an ABC system, it is practically useful to start with a small group (pilot group) of well-informed and cross-functional workers. The team should interview other workers about what they do in their jobs. The team members should be cognizant of the potential fears of job restructuring that some employees may have as a result of the ABC studies.

The team should start with the "worst" department so that immediate success may be used to get faster "buy-in" from top management. The key for achieving ABC success is to use "close-enough" data, and keep the level of information manageable by avoiding being bogged down with minute details. On the other hand, an ABC system that is too broad and general will yield no useful results. The team may have to try out ABC cost models of different granularities on small scales. When applying ABC cost models for the very first time, useful outputs can be expected in 6–12 months. Illustrative examples for creating an ABC cost model are shown in the next section.

6.3 Application of ABC in Industry

6.3.1 Application: Manufacturing Operations

XYZ is a small manufacturing company with $10 million in annual sales. It makes components for the automotive industry, involving the key production processes of forging and machining. Its product-related operating activities are as follows:

1. Buying steel bars from outside vendors.
2. Testing steel bars on receipt and moving them to storage.
3. Sending the bars to the forging area when needed for a customer order, at which point they are sandblasted and cut to desired lengths. Since most of the bars are large, they are then moved in bins that hold 20–25 pieces.

4. Sizing the bars and moving them to a forging station where they are shaped. The bars are then moved to the in-process storage. In some cases, a steel bar may need to be forged up to three times.
5. Transferring the bars for each forging procedure from in-process storage to the forging station and then back to the in-process storage.
6. Moving the steel bars after the final forging from the in-process storage to the machining station where they are finished. The bars are then sent to the finished-goods storage.
7. Sorting, packing, and loading the bars is done in the shipping area and onto trucks for delivery to customers.

Before using ABC, the company applied the traditional costing method that included the following steps: (1) Assign manufacturing costs to products by using a plantwide costing rate on the basis of DL. The setup costs are included in the manufacturing overhead. (2) Assign the nonmanufacturing costs to products via a general and administrative (G&A) rate that is calculated as a percentage of the total cost. (3) Define the DL rate and the G&A rate on the basis of the actual results obtained for the preceding year. The deficiencies of the traditional method are obvious. The traditional method is used because management does not see a need for change.

When implementing ABC, the company did not buy any ABC-specific software. Instead, they used a standard Excel spreadsheet program. Typically, the company considered the following factors:

1. *Setup costs*: Management assigned equipment setup costs only to the steel bars in a given equipment process.
2. *Forging costs*: Depending on the weight of the steel bar involved, one or two operators may operate the forging press. Prior to forging, each steel bar must be induction heated, with the heating cost being dependent on the mass of the bar involved. Thus, the forging cost consists of three parts:
   a. Press-operating costs on the basis of forging press usage (in hours).
   b. Production labor cost on the basis of labor hours spend.
   c. Induction-heating costs on the basis of the steel bar's weight
3. *Machining costs*: The machining centers do not require full-time operators. Once the machines are set up, workers load and unload parts for multiple centers. On average, one machine-worker hour is required for every two and a half machine hours. Thus, the costs of machine-shop workers are treated as the indirect costs assigned to products on the basis of machine hours.
4. *Material movement costs*: Depending on the size of the bar, the bin size, and the required forging and machining steps, the material movement cost could vary significantly from one bar to another. Thus, the material movement cost is assigned to each bar on the cost-per-move basis.
5. *Raw material procurement and order processing costs*: These are readily traceable on the basis of records on hand.

The ABC cost model for the XYZ manufacturing company is illustrated in Table 6.2.

TABLE 6.2
ABC Model for XYZ Manufacturing Company

	Forging Press Hour Cost	Machine Hour Cost	Induction Heating Cost	Material Movement Cost
Directly Attributable Costs	Depreciation	Depreciation	Depreciation	Depreciation
	Utilities	Utilities	Utilities	Utilities
	Manufacturing supplies	Manufacturing supplies	Manufacturing supplies	Manufacturing supplies
	Outside repairs	Outside repairs	Outside repairs	Outside repairs
	—	Straight-line wages	—	Straight-line wages
	—	Fringe benefits	—	Fringe benefits
	—	Payroll taxes	—	Payroll taxes
	—	Overtime premium	—	Overtime premium
	—	Shift premium	—	Equipment leases
Distributions	Maintenance	Maintenance	Maintenance	Maintenance
	Buildings and grounds	Buildings and grounds	Buildings and grounds	Buildings and grounds
	Manufacturing engineering	Manufacturing engineering	Manufacturing engineering	Human resources
	Commodity overhead	Commodity overhead	Commodity overhead	Supervision
	—	Supervision	—	—
Total	Total costs	Total costs	Total costs	Total costs
Rate	Dollar per press hour	Dollar per machine hour	Dollar per heating weight	Dollar per move

It produced cost data of an increasingly detailed nature regarding the production cost for various customer contracts. These insights allowed management to define a more profitable mix of contracts generated by a pricing and quoting process that more closely reflects the actual cost structure of the company. Particularly useful are the isolation and measurement of material movement costs that result in operational changes for increased efficiency. The final results of ABC implementation are impressive. The company's sales tripled and its profit increased fivefold after having implemented new operational strategies based on new outcomes of the ABC study.

6.3.2 Application: Banking and Financial Services

Buckeye National Bank (Bamber and Hughes 2001) services both retail and business customers. The services include paying checks, providing teller services, and responding to customers' service calls. All of these services consume labor-intensive activities. The resources involved are employees (salary and benefits), part-time workers, and those related to the operation of service call centers. The bank's traditional costing system suggests that it is more profitable for the bank to pursue more retail customers and that business customers bring losses. As a result, the bank's retail customers grow, while the business customers remain stable. Yet, the bank's profit is trending downward. Bank management becomes puzzled as to the reasons why.

A large number of cost data were made available from the banks' traditional accounting system. Tables 6.3 and 6.4 display these data.

The solution obtained based on the traditional costing system is shown in Table 6.5. It indicates that the annual profit of the retail account is $8.10 whereas that of the business account shows a loss of $11.30. The logic of pursuing more retail customers appear to be correct.

An ABC pilot study was initiated to define (1) the percentage of time each employee spends on the aforementioned three activities; and (2) costs associated with toll-free phone lines, depreciation of equipment used for paying checks, and providing teller services. The cost drivers were identified to be (1) the number of checks processed for the paying check activity, (2) the number of teller transactions for the activity related to providing teller service, and (3) the number of calls received for activity related to responding to customer inquiries.

TABLE 6.3

General Ledger Cost Data of Buckeye Bank

Buckeye National Bank	Dollar Value
Salaries of check-processing personnel	$700,000
Depreciation of equipment used in check processing	$440,000
Teller salaries	$1,000,000
Depreciation of equipment used in teller operations	$200,000
Salaries of call center personnel	$450,000
Tool-free phone line plus depreciation of related equipment	$60,000
Total costs	$2,850,000
Total profit	$650,000

TABLE 6.4

Additional Cost Data of Buckeye National Bank

	Retail	Business
Dollar value of check processed	$9,500,000	$85,500,000
Checks processed	570,000	2,280,000
Teller transactions	160,000	40,000
Number of customer calls	95,000	5,000
Annual profit (interests) per account	$10	$40

TABLE 6.5

Traditional Cost Solutions

Traditional System	Retail	Business
Dollar value of check processed	9,500,000	85,500,000
Cost per dollar processed	$0.03	$0.03
Total cost	$285,000	$2,565,000
Cost per account	$1.90	$51.30
Annual profit per account	$8.10	($11.30)

TABLE 6.6

Unit Costs of Three Principal Activities

ABC Solutions		
Cost per check processed	$0.40	(= 700K + 440K)/2850
Cost for teller transition	$6.00	(1000K + 200K)/200K
Customer inquiries	$5.10	(450K + 60K)/100K

TABLE 6.7

Cost Assignments and Per Account Cost

ABC Cost Assignment	Retail	Business
Paying checks (0.4*570K)	$228,000	912,000
Teller transactions (6*160)	960,000	240,000
Call centers (5.10*95,000)	484,500	25,500
Total	1,672,500	1,177,500
Per account cost	$11.15	$23.55
Net profit per account	−1.15	16.45

Table 6.6 summarizes the unit cost of the three activities. Table 6.7 shows the cost assignments and the per account cost. In fact, the retail accounts are shown to lose money, indicating that the bank policy of pursuing retail customers was based on an incorrect costing data.

6.4 Risk Analysis and Cost Estimation under Uncertainty

When estimating costs for products and services, some part of these costs are well defined and firm, while others are not. Similarly, some projects in engineering based on past experience are risk free, while others are not. Risks are defined as a measure of the potential variability of an outcome (e.g., cost or schedule) from its expected value. Risks must be properly accounted for in projects (Ayyub 2014; Cox 2015).

6.4.1 Representation of Risks

Risks can be graphically represented by a probability distribution function. Three cases are examined next.

Figure 6.1 shows that the yield of 10-year U.S. Treasury bills has varied in the range of 8% (1990) to below 4% (2002). But once an investor purchases the Treasury bills from the U.S. government, the yield is locked in until maturity. Such an investment is guaranteed by the assets of the U.S. government. This return is graphically represented by a vertical line at a fixed return rate (6% assumed in this example) with 100% probability (see Figure 6.2, Case 1).

Case 2 is an investment in a blue-chip corporate stock with a most likely return of 8%. Due to market conditions being usually unpredictable, the return of such an investment has some measure of risk, as represented by the bell-shaped curve centered on 8%

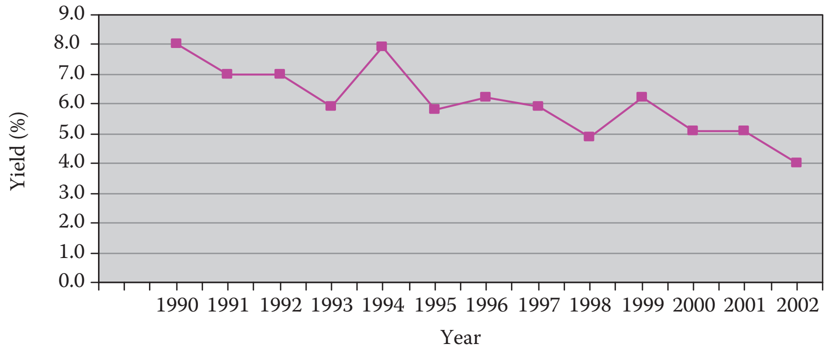

FIGURE 6.1
Yield of U.S. Treasury Bill.

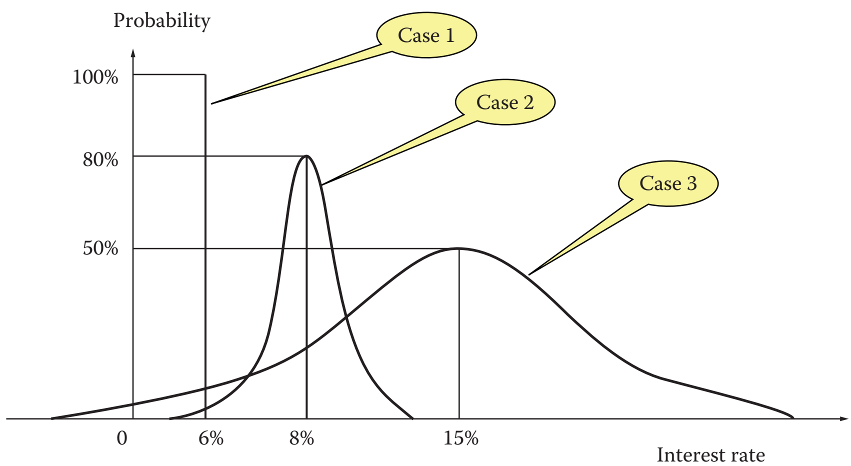

FIGURE 6.2
Graphical representation of risks.

in Figure 6.2. The return may vary from 4% (minimum) to 12% (maximum). Risks are measured by the standard deviation of this probability distribution curve (e.g., σ_2) (see Figure 6.2, Case 2).

The bell-shaped curve is mathematically represented by the Normal probability density function,

$$F(x) = \frac{1}{\sigma_x\sqrt{2\pi}} e^{-\frac{1}{2}\left(\left((x-\mu)/\sigma_x\right)^2\right)} \tag{6.1}$$

where:

$\sigma =$ standard deviation
$\mu =$ mean
$\pi = 3.14159$

The area underneath the curve is normalized to be 1.

Case 3 is the return of an investment in real estate, centered, for example, around 15%. Because this investment requires tax payment, maintenance costs, and other expenditures, its minimum return may be negative. Its upside potential may be very large, however, if commercial developments and property-zoning results become favorable. This case is represented by a bell-shaped probability curve having a large standard deviation (σ_3 being larger than σ_2) and with its most likely return centered around 15%. Furthermore, the probability of achieving its most likely return of 15% is now only 50% (see Figure 6.2.).

Risky events may be represented mathematically by the Normal probability density function, which is defined by two parameters, standard deviation and mean. Besides the Normal, several other probability density functions (such as Triangular, Poisson, and Beta) may also be used to represent risky costs (see Section 6.4.3).

6.4.2 Project Cost Estimation by Simulation

Recent literature outlines the advancements of PC-based techniques that estimate project costs under uncertainty (Zio 2012; Gupta 2013). The key elements of these PC-based techniques consist of the following steps:

1. Construct a *cost model* for the projects at hand with a spreadsheet program (e.g., Excel) (Bodnar and Hopwood 2012). The spreadsheet program takes care of the required computation of the cost model, such as addition, subtraction, multiplication, and division. The numerical values entered in the spreadsheet cells are typically deterministic, each having a well-defined and fixed magnitude. The cost model encompasses all cost components and computes the total project cost.
2. Make a *three-point estimate* for each of the component costs, composed of the minimum, the most likely, and the maximum values. This is to account for the perceived-cost uncertainty. Past experience may serve as a guide in the selection of these values.

   Select a probability distribution function (e.g., Triangular, Normal, Beta, or other distribution functions) to represent the three-point estimate of the component cost. Repeat this step for all other cost components of the project.
3. Activate *risk analysis software* to replace the deterministic values contained in the spreadsheet cells by the probability distribution functions chosen to represent the corresponding three-point estimates.

   Currently, commercial PC-based software products are readily available. Some examples are

   a. CrystalBall® for Excel (Charnes 2012), see Crystal Ball software at www.oracle.com
   b. @Risk (Version 6) and BestFit programs (Palisade Corp.) for Excel spreadsheet (Nersesian 2011)

   The BestFit program marketed by Palisade Corporation may be used to define a suitable probability distribution function on the basis of numerical three-point estimates or other user-specified input data.

   The activated risk analysis software automatically converts all input probability density functions to their corresponding cumulative distribution functions. The technical fundamentals related to this conversion are illustrated in Appendix 6.I.

4. Conduct a Monte Carlo simulation to compute the total project cost. Upon activation of risk analysis software, a random number is first generated between 0 and 1. This random number represents a trial probability value (e.g., P1). Using this random number, the specific cost value is read from the cumulative distribution of the cost component C1, which represents a random input variable (e.g., C11, see Figure 6.3). A second random number is generated (P2), which is then used to define the cost of the cost component C2 (e.g., C21). A third random number is generated to define the cost C31 of a third cost component. This process is continued until the costs of all cost components are defined. The total project cost (e.g., TPC1) is then calculated with the spreadsheet program that contains the cost model. This is one outcome of the random output variable TPC.

   This sampling process is repeated thousands of times to create a distribution of the total project costs (e.g., TPC1, TPC2). These output results are then statistically grouped into bins (with zero to maximum value) to come up with a cumulative distribution. The resulting cumulative distribution for the total project cost TPC may then be converted back to its corresponding probability density function.

   The total project cost so generated has a set of minimum, most likely, and maximum values.

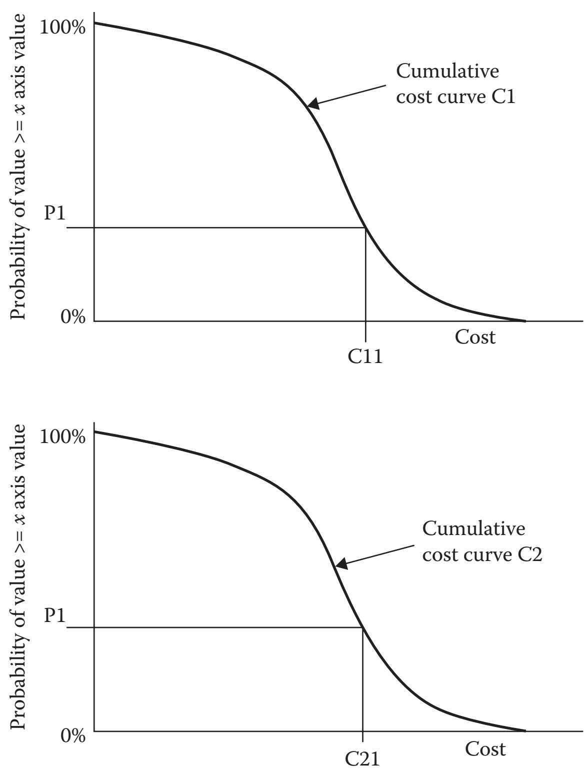

FIGURE 6.3
Cumulative distribution functions.

5. Interpret the *total project cost* represented in a cumulative distribution to arrive at the following typical results:
   a. There is an 80% probability that the total project cost will not exceed $D.
   b. The minimum, most likely, and maximum total project costs are $A, $B, and $C.
   c. The standard deviation of the total project cost is x, or the overall measure of the project risk.

Information of this type is extremely useful for decision-making. It is particularly true in situations where multiple projects are being evaluated for investment purposes.

There is an additional benefit realized by using the just-described cost estimation by simulation. Because of the "risk pooling" effect, due to risk sharing among all input cost components, the total project cost is expected to have a lower overall risk than the risk levels of its individual components. Various studies (e.g., Canada et al. 2004), have confirmed that the total project cost computed by simulations requires a smaller contingency cost for a given risk level than that computed by the traditional method by using deterministic values.

Other important applications involving risk analyses include (1) project schedule and (2) portfolio optimization.

Risk analyses are capable of making explicit the uncertainties of input variables, promoting more reasoned estimating procedures, allowing more comprehensive analyses—or the simultaneous variation of all input variables involved—and measuring the variability of output variables. Having a fuller understanding of the risk-based implications of the decision will enable a decision-maker to make better decisions.

The use of risk analysis in the business and engineering environments is expected to become increasingly widespread in the years to come. Managers are advised to become familiar with such advanced tools for risk analyses.

6.4.3 Examples of Input Distribution Functions

In engineering cost estimation, several distribution functions are often used as inputs. Figure 6.4 shows the Triangular probability density function. This is the easiest function to apply, as the three-point estimates may be directly incorporated into this representation.

Figure 6.5 illustrates the Normal probability function. Figure 6.6 displays the Beta probability density function. Figure 6.7 depicts the Poisson probability function.

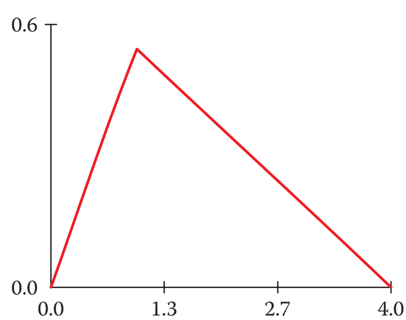

FIGURE 6.4
Triangular distribution function.

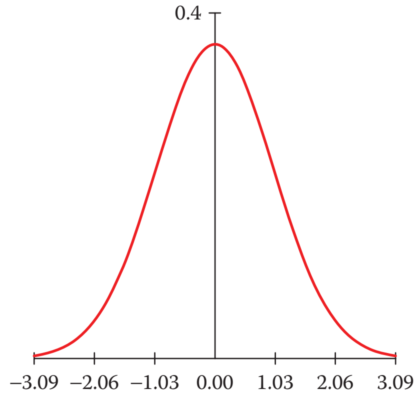

FIGURE 6.5
Normal distribution function.

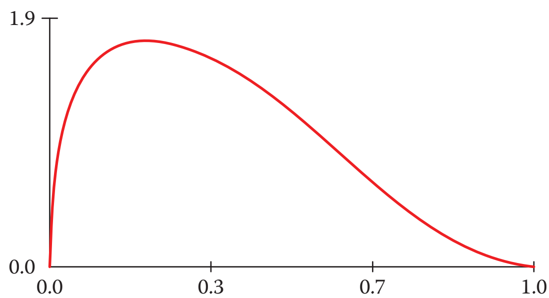

FIGURE 6.6
Beta distribution function.

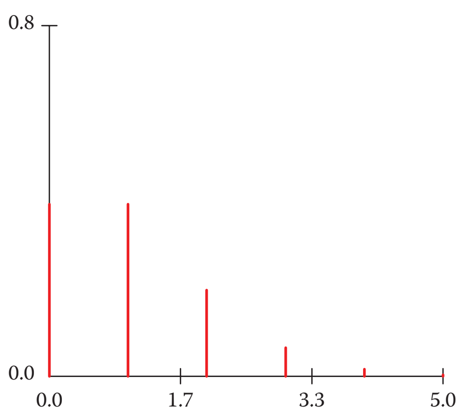

FIGURE 6.7
Poisson distribution function.

6.4.4 Application: Cost Estimation of a Risky Capital Project

Capital projects are those encompassing the design, procurement, installation, and testing of major equipment, including the proper preparation of foundation and the activation of the required instrumentation system. Capital projects may be found in many industries. This section shows the cost estimation for a turnkey capital project (Table 6.8).

Typically, project managers define the base (e.g., the most likely) estimates, as well as the lower and upper bounds for each cost item in the estimate. Doing so will force them to externalize the reasons for any variance that may be expected and require them to think hard in preparing the contingency plans for each.

The output total cost is represented by the probability density and cumulative distribution functions (see Figures 6.8 and 6.9).

From the output cumulative distribution, the following results are readily obtained:

1. The most likely total project cost is $5,136,000, which, of course, only echoes the input data.
2. There is an 80% probability that the project cost will exceed $5,100,000.
3. There is a 20% probability that the project cost will exceed $5,170,000.
4. The maximum project cost is $5,250,000.
5. The minimum project cost is $4,989.71.

Note that the information offered by items B, C, D, and E is new. In a traditional, deterministic project cost estimate, the cost figures for items A, D, and E would be the same,

TABLE 6.8

Cost Model of a Capital Project

#	Cost Category	Base ($K)	Min (%)	Max (%)	Minimum ($)	Most Likely ($)
1XXX	Cold box	$748.00	−5	5	$710.60	$748.00
2XXX	Rotating equipment	$742.00	−3	3	$719.74	$742.00
3XXX	Process equipment	$658.00	−2	5	$644.84	$658.00
4XXX	Electrical equipment	$194.00	−5	3	$184.30	$194.00
5XXX	Instrumentation	$295.00	−2	10	$289.10	$295.00
6XXX	Piping mat/specials	$121.00	−2	10	$118.58	$121.00
711X	Civil construction	$284.00	−2	5	$278.32	$284.00
712X	Mechanical construction	$390.00	−1	20	$386.10	$390.00
713X	Electrical construction	$85.00	−2	10	$83.30	$85.00
71?X	Other contracts	$83.00	−5	10	$78.85	$83.00
716X	Purchased enclosures	$48.00	−5	12	$45.60	$48.00
717X	Fabrication	$179.00	−5	4	$170.05	$179.00
7890	Freight	$80.00	−5	15	$76.00	$80.00
84X0	Field support	$188.00	−5	7	$178.60	$188.00
85XX	Start-up	$60.00	−10	30	$54.00	$60.00
81X0	Product line design	$516.00	−1	15	$510.84	$516.00
8150	Project execution	$333.00	−5	20	$316.35	$333.00
	Total neat	$5004.00				
	Contingency	$131.90				
	Grand total	$5135.90				

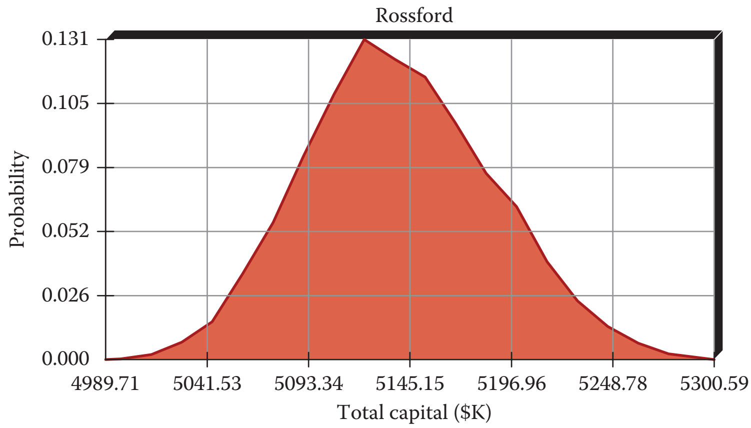

FIGURE 6.8
Total capital cost represented in a probability density function.

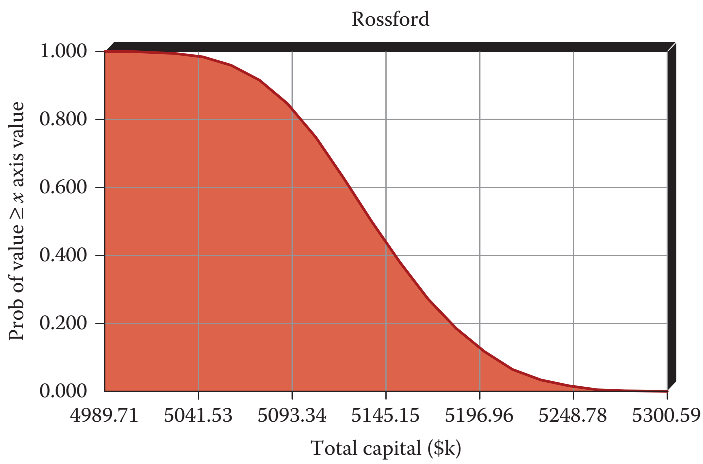

FIGURE 6.9
Total capital cost presented in a cumulative distribution function.

and there would be no information of the kind offered by items B and C. When choosing among various projects that may have similar outcomes in the most likely project costs, information offered by items B and C is especially useful in differentiating projects by their inherent risks.

For construction managers, the estimation of contingency is of critical importance. Instead of assigning specific contingencies as a percentage to each cost category items, the simulation described in this section calculates the contingency cost of the entire construction project. Probabilistic models have been used in the past to define construction project contingency (Cook 2012).

In addition, project control and tracking of coefficient of variation can be readily conducted (see Figures 6.10 and 6.11). The coefficient of variation is defined as CV = 100 (σ/μ), wherein σ is the standard deviation and μ is the mean of the total project cost distribution function.

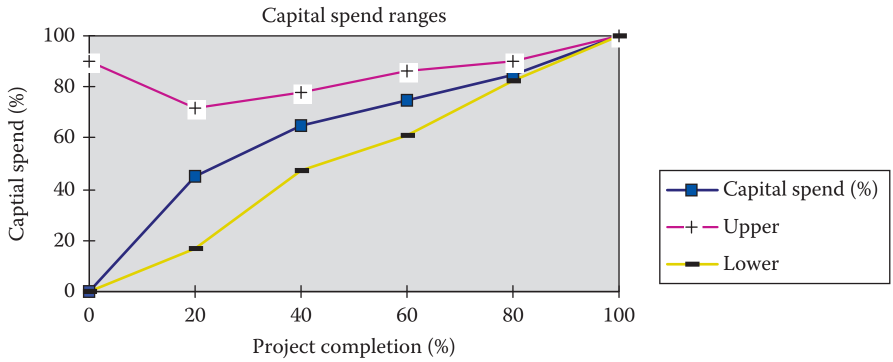

FIGURE 6.10
Project control and tracking.

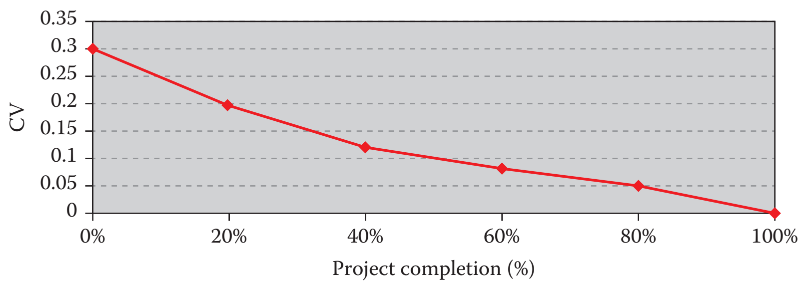

FIGURE 6.11
Coefficient of variation.

6.4.5 Other Techniques to Account for Risks

Several other techniques are also routinely applied in industry to assess and manage the risks associated with projects:

1. *Sensitivity analysis*: Because of possible variation of specific input parameters, "what-if" analyses are typically performed to assess the sensitivity of the project cost and time to completion (Saltelli et al. 2009).
2. *Contingency cost estimation*: The cost of a risky project may be estimated by adding a contingency cost to each task (typically 5%–7% of the task cost) to cover the risk involved (Downs 2013). These specific percentage numbers are selected based on industrial best practices.
3. *Decision trees*: Decision trees are used to evaluate sequential decisions and decide on alternatives on the basis of the expected values of probabilistic outcomes (Stevens 2014).
4. *Diversification*: With this risk management technique, several risky projects can be engaged in at the same time to spread the risks by means of diversification—combining high-risk, high-return projects with low-risk, low-return projects—to achieve a reasonable overall return on investment (Hull 2014; Badea and Grigorescu 2014).

5. *Fuzzy logic systems*: These systems of reasoning are based on fuzzy sets (Ross 2010; Nguyen and Walker 2005). A fuzzy set defines the range of values for a given concept as well as the degree of membership. A membership of 1 indicates full membership, whereas 0 defines exclusion. The change of membership from 0 to 1 is gradual. For example, a fuzzy expert system employs rules such as the following:

If the temperature T is high (A_i) and the difference in temperature is small (B_i), then close the valve V slightly (S_i), wherein A_i, B_i, and S_i are fuzzy sets. Fuzzy logic systems have been applied to assess project risks (Trilla 2015).

Example 6.1

The company needs to decide either to develop a new product with an investment of \$400,000 or to upgrade an existing product by spending \$200,000, as illustrated by the decision point 1 in Figure 6.12.

1. If the new product strategy is pursued, then there is a 60% probability that the product will be in high demand, in which case the company will make \$200,000 next year. Concurrently, there is a 40% chance for low demand, which will result in a loss of \$100,000 for the company next year (see Node A in the decision tree diagram in Figure 6.12).

   If the new product enjoys a high demand, then there is an 80% chance that the product will earn \$1,000,000 and a 20% chance it will earn only \$50,000 in the year after the next (see Node a in Figure 6.12). If the new product meets a low demand, then there is a 30% chance for a revenue of \$500,000 and a 70%

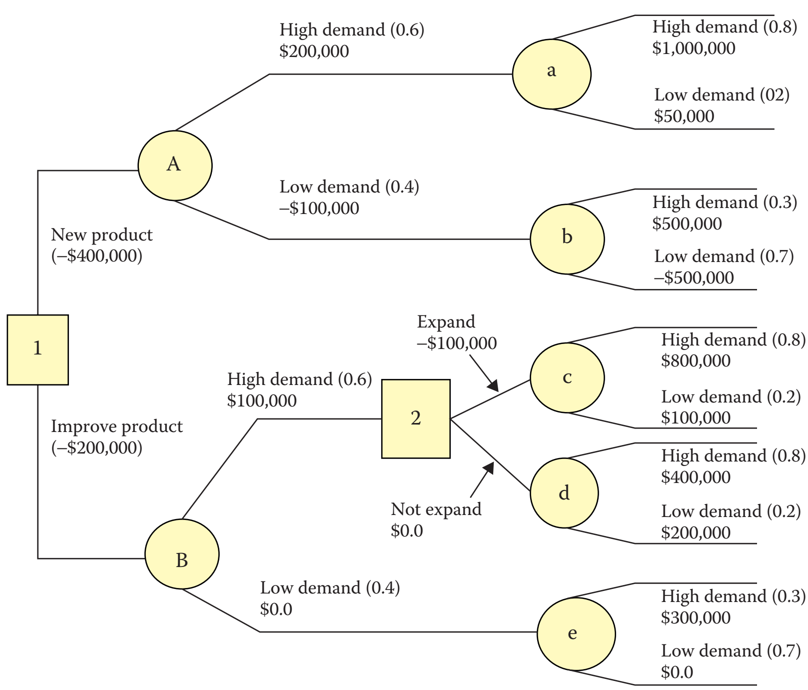

FIGURE 6.12
Decision tree analysis.

chance of suffering a loss of $500,000 in the year after next (see Node b in Figure 6.12).
2. If the company follows the strategy of improving the existing product, then there is a 60% chance of high demand, leading to a revenue of $100,000; and a 40% chance of low demand, to yield zero revenue in the first year (see Node B in Figure 6.12).

If the demand is high at the end of the first year, the company needs to make a second decision (Decision Point 2) whether or not to expand the product line. The expansion option will require a new investment of $100,000, whereas the option of no expansion costs nothing. If the company expands the improved product line, then there is an 80% chance that it will reap a revenue of $800,000 and a 20% chance of $100,000 revenue in the year after the next (see Node c in Figure 6.12). If the company elects not to expand at the end of the first year, then there is an 80% chance it will realize a revenue of $400,000 and a 20% chance of $200,000 revenue (see Node d in Figure 6.12).

Should the improved product of the company see a low demand (at a probability of 40%) and get zero revenue in the first year, then there is a 30% chance that the product can generate revenue of $300,000 and a 70% chance of zero revenue (see Node e in Figure 6.12).

The interest rate is 10%. This problem is fully diagrammed in Figure 6.12. Determine which decisions at Decision Points 1 (product strategy) and 2 (expansion strategy) the company should make.

Answer 6.1

This problem can be solved by using the decision tree method, which works from right to left, from future (the year after next) to present.

1. *Decision Point 2*
   At Node c, the expansion option has a total expected return of

$$\text{ER}(\text{c}) = 0.8(\$800{,}000) + 0.2(\$100{,}000) = \$660{,}000$$

   At Node d, the no-expansion option has a total expected return of

$$\text{ER}(\text{d}) = 0.8(\$400{,}000) + 0.2(\$200{,}000) = \$360{,}000$$

   The present value of expansion is

$$\text{PV}(\text{Expansion}) = -\$100{,}000 + \text{ER}(\text{c}) / 1.1 = \$500{,}000$$

   And the present value of no expansion is

$$\text{PV}(\text{No Expansion}) = 0 + \text{ER}(\text{d}) / 1.1 = \$327{,}272$$

   Based on these present values, the decision should favor expansion.
2. *Decision Point 1*
   At Node a, the total expected return is

$$\text{ER}(\text{a}) = 0.8(\$1{,}000{,}000) + 0.2(\$50{,}000) = \$810{,}000$$

At Node b, the corresponding total expected return is

$$\mathrm{ER}(\mathrm{b}) = 0.3(\$500{,}000) + 0.7(-\$500{,}000) = -\$200{,}000$$

Thus, the present value for the high-demand case is

$$\mathrm{PV}(\text{High Demand}) = \$200{,}000 + \mathrm{ER}(\mathrm{a}) / 1.1 = \$936{,}363$$

The present value for the low-demand case is

$$\mathrm{PV}(\text{Low Demand}) = -\$100{,}000 + \mathrm{ER}(\mathrm{d}) / 1.1 = -\$281{,}818$$

Thus, the present value for the new product strategy is

$$\mathrm{PV}(\text{New Product}) = -\$400{,}000 + \left[0.6\mathrm{PV}(\text{High Demand}) + 0.4\mathrm{PV}(\text{Low Demand})\right] / 1.1 = \$8{,}264$$

On the other hand, for the product improvement strategy we have

$$\mathrm{PV}(\text{High Demand}) = \$100{,}000 + \mathrm{PV}(\text{Expansion}) = \$600{,}000$$

(Note that the no-expansion option is abandoned.)
The present value of low demand is

$$\mathrm{PV}(\text{Low Demand}) = 0 + \mathrm{ER}(\mathrm{e}) / 1.1 = 0 + \left[0.3(\$300{,}000) + 0.7(0)\right] / 1.1 = \$81{,}818$$

Thus, the present value for the product improvement strategy is

$$\mathrm{PV}(\text{Product Improvement}) = -\$200{,}000 + \left[0.6(\$600{,}000) + 0.4\ (\$81{,}818)\right] / 1.1 = \$157{,}024$$

Since the present value for improving the product is larger than the present value for a new product, the choice should be in favor of product improvement.

Even if the company decides to forgo expansion at Decision Point 2, the present value for product improvement is

$$\mathrm{PV}(\text{Product Improvement with No Expansion}) = -\$200{,}000 + [0.6(\$427{,}272) + 0.4(\$81{,}818)] / 1.1 = \$62{,}808$$

which is still larger than that for new product development. Thus, the value of expansion is

$$\mathrm{Value}(\text{Expansion}) = \$157{,}024 - \$\$62{,}809 = \$94{,}215$$

6.5 Miscellaneous Topics

This section discusses several miscellaneous topics, including economic quantity of ordering, simple cost-based decision models, and project evaluation criteria.

6.5.1 Economic Quantity of Ordering

The procurement costs of parts, materials, and other supply items directly affects total product costs. The ordering process must take into account the quantity needed, purchase price, order processing fees, shipping costs, and the time value of money. Managers may need to know how to arrive at the *economic quantity of ordering* in order to minimize the total cost of procurement. The next example illustrates this concept.

Example 6.2

A manufacturing company buys 6000 steel bars a year at a fixed price of \$18 each. It costs the company \$85 to process and place each order. Assuming 10% interest compounded annually, what is the most economic quantity to order at one time?

Answer 6.2

Let

$N =$ Number of orders placed in a year
$C =$ Total cost of ordering at year end

$$N = 1: \quad C = 6000 \times 18(1 + 0.1) + 85$$

$$N = 2: \quad C = 3000 \times 18(1 + 0.1) + 85 + 3000(18)\left(1 + \frac{0.1}{2}\right) + 85$$

$$N = 3: \quad C = 2000 \times 18(1 + 0.1) + 85 + 2000(18)\left(1 + 0.1\tfrac{2}{3}\right) + 85$$
$$+ 2000 \times 18\left[1 + 0.1(1/3)\right] + 85$$

Hence,

$$N = N: \quad C = 6000 \times 18(1/N)[N - (0.1/N)(N + (N-1) + (N-2) + \cdots + 1)] + 85N$$

To find the minimum C by differentiation,

$$dC/dN = 0 = 5400\left(1/N - (N+1)/N^2\right) + 85$$
$$N = 7.98 = 8$$
$$6000/8 = 750$$

The economic quantity to order is 750 units, and eight times per year (every 6.5 weeks).

6.5.2 Simple Cost-Based Decision Models

Engineering managers need to make regular choices among alternatives. In some cases, such choices may be made based on costs, as illustrated by the following two examples (Mehta 2015).

1. *Comparison of alternatives:* When faced with the option of purchasing one of several sets of capital equipment with similar functional characteristics, engineering managers can use the following annual cost formula to identify which has the lowest total annual cost.

   The annual cost for a long-lived asset is defined as the sum of its depreciation charge, interest charge for the capital tied down by the purchase, and its annual operational expenses; that is,

$$\mathrm{AC} = \frac{(P-L)\times i}{(1+i)^N - 1} + P\times i + \mathrm{AE} \tag{6.2}$$

   where:
   P = Initial investment (dollars)
   N = Useful life of a long-lived asset (years)
   L = Salvage value (dollars)
   i = Interest rate (percent)
   AE = Annual expenses (dollars)—taxes, supplies, insurance repairs, utilities, etc.
   AC = Annual cost (dollars)

   The capital equipment with the lowest AC is preferable. (The derivation of both the approximate and exact methods is shown in Appendix 6.H)

Example 6.3

Your company has averaged 15% growth per year for the past seven years, and now you need additional warehouse space for purchased material as well as FG. Two types of construction have been under consideration: conventional and air-supported fabric. (The data are available in Table 6.9.)

Which is the better economical choice?

TABLE 6.9

Warehouse Options

Type	Conventional	Air Supported
First cost ($)	200,000	35,000
Life (years)	40	8
Annual maintenance ($)	1,500	5,000
Power and fuel ($)	700	5,500
Annual taxes (%)	1.5	1.5
Salvage value ($)	40,000	3,000
Interest rate	0.08	0.08

Answer 6.3

Conventional:

$$\mathrm{AC}_1 = (200{,}000 - 40{,}000) \times \frac{0.08}{\left[1.08^{40} - 1\right]} + 200{,}000 \times 0.08$$

$$+\left[1{,}500 + 700 + 1.5(200{,}000/100)\right] = \$21{,}818$$

For air supported:

$$\mathrm{AC}_2 = (35{,}000 - 3{,}000) \times \frac{0.08}{\left[1.08^{8} - 1\right]} + 35{,}000 \times 0.08$$

$$+\left(5{,}000 + 5{,}500 + 1.5 \times \frac{35{,}000}{100}\right) = \$16{,}833$$

Choice: Air-supported system.

Example 6.4

A semiautomatic machine is quoted at \$15,000, while an advanced machine is quoted at \$25,000. The salvage value of these machines is assumed to be zero. A four-man party can produce 500 parts a day with the semiautomatic machine, by using a machinist at \$200 per day, a maintenance worker at \$150 per day, a parts laborer at \$100 per day, and a warehouse clerk at \$80 per day.

A six-man party can produce 770 parts a day with the advanced machine, using a machinist at \$200 per day, an assistant machinist at \$180 per day, a maintenance worker at \$150 per day, two parts laborers at \$100 per day each, and a warehouse clerk at \$80 per day.

Material cost is \$10 per part. The FO is 50% of the DL cost, only when parts are being produced. Maintenance expense for the semiautomatic machine is \$250 per year, and for the advanced machine is \$500 per day. The estimated life of the semiautomatic machine is 20 years, and 15 for the advanced machine. The cost of money is 8% per year.

How many parts must be made per year to justify the procurement of the advanced machine?

Answer 6.4

Define x = number of parts produced per year
y = number of working days to produce parts
For the semiautomatic machine: $y = x/500$
For the advanced machine, $y = x/770$ (see Table 6.10).

The annual cost of operating the semiautomatic machine is given by

$$\mathrm{AC}_{\mathrm{semi}} = \frac{15{,}000 \times 0.08}{(1.08)^{20} - 1} + 15{,}000 \times 0.08 + 250 + 10 \times x + 530\,\frac{x}{500} \times 1.5$$

$$= 1777.78 + 11.59x$$

TABLE 6.10

Comparison of Two Machines

	Semiautomatic	Advanced
First cost ($)	15,000	25,000
Daily production	500	770
Daily wage ($)	530	810
Annual maintenance ($)	250	500
Life (years)	20	15
Material cost ($ per part)	10	10
FO (%)	50	50
Interest	0.08	0.08

The annual cost of operating the advanced machine is given by

$$\mathrm{AC}_{\mathrm{adv}} = \frac{25,000 \times 0.08}{(1.08)^{15} - 1} + 25,000 \times 0.08 + 500$$

$$+10 \times x + 810\left(\frac{x}{770}\right) \times 1.5 = 3420.74 + 11.57792x.$$

Setting $\mathrm{AC}_{\mathrm{semi}} = \mathrm{AC}_{\mathrm{adv}}$, we have

$$1777.78 + 11.59x = 3420.74 + 11.57792x$$

$$x = 136.172$$

The advanced machine is justifiable if the production exceeds 136,172 parts per year.

2. *Replacement evaluation*: Engineering managers are sometimes faced with the decision of whether to replace an existing facility with a brand-new one. Again, this replacement decision may be made by identifying the option with the lowest annual cost.

   In this analysis, the existing facility is treated as if it is new, in that its residual equipment life and its residual book value (initial capital investment minus accumulated depreciation) are equivalent, respectively, to the useful product life and the capital investment cost of new equipment. Thus,

$$\mathrm{AC}_{\mathrm{o}} = \frac{i \times \left[\mathrm{BV}(t) - L_{\mathrm{o}}\right]}{(1+i)^{(N_{\mathrm{o}}-t)} - 1} + \mathrm{BV}(t) \times i + \mathrm{AE}_{\mathrm{o}} \tag{6.3}$$

$$\mathrm{AC} = \frac{i \times [P - L]}{(1+i)^{N} - 1} + P \times i + \mathrm{AE}, \tag{6.4}$$

where:

P_{o} = Original investment cost of the existing machine (dollars)

N_{o} = Original estimate of useful life of the existing machine (years)

$\mathrm{AE_o}$ = Annual expenses of using the existing machine (dollars)
L_o = Salvage value of the existing machine at the end of its useful life (dollars)
t = Present age of the existing machine (years)
$N_o - t$ = Remainder life of the existing machine (years)
$\mathrm{BV}(t)$ = Book value of existing equipment at the end of the tth year (dollars)
P = Initial investment of the replacement equipment (dollars)
AC = Annual cost of using the replacement equipment (dollars)
L = Salvage value of the replacement machine at the end of its useful life (years)
N = Useful life of the replacement equipment
AE = Annual expenses for using the replacement equipment (dollars)

If AC_o is larger than AC, it is recommended to use the replacement equipment to save costs.

Example 6.5

A compressor air-supply station was built 18 years ago at the main shaft entrance to a coalmine at a cost of $2.6 million. The station was equipped with steam-driven air compressors that have an annual operating expense of $360,000. The salvage value at the estimated 25-year life of the station is $130,000. It can be sold now for $800,000.

A proposal has been made to replace the station with electrically driven compressors that would be installed underground near the working face of the mine for a cost of $2.8 million. The new compressor station would have a life of 30 years and a salvage value of 10%. Its annual operating cost would be two-thirds of the steam-driven station. Annual taxes and insurance are 2.5% of the first cost of either station. The interest rate is 8% per year. Is there a financial justification to replace the steam station?

Answer 6.5

Table 6.11 summarizes the data of these two compressors.

Assuming approximate method (straight-line depreciation):

$$\text{Steam:}\quad \mathrm{AC} = \left(\frac{800{,}000 - 130{,}000}{7}\right) + (800{,}000 - 130{,}000) \times \frac{0.08 \times 8}{2 \times 7}$$
$$+130{,}000 \times 0.08 + 425{,}000 = \$561{,}742.86$$

TABLE 6.11

Comparison of Two Compressor Drives

	Steam	Electric
Original investment ($)	2,600,000	2,800,000
Life (years)	25	30
Present age (years)	18	0
Remaining life (years)	7	30
Present salvage value ($)	800,000	—
Final salvage value ($)	130,000	280,000
Annual expense ($)	360,000 + 65000	240,000 + 70,000

$$\text{Electric:}\quad \text{AC} = \frac{2{,}800{,}000 - 280{,}000}{30} + (2{,}800{,}000 - 280{,}000) \times \frac{0.08 \times 31}{2 \times 30}$$

$$+280{,}000(0.08) + 312{,}500 = \$523{,}060$$

Answer: Replace the old steam unit.
Assume the exact method for calculating depreciation (sinking fund):

$$\text{Steam:}\quad \text{AC} = (800{,}000 - 130{,}000) \times \frac{0.08}{1.08^7 - 1} + 800{,}000 \times 0.08$$

$$+425{,}000 = 564{,}088.50$$

$$\text{Electric:}\quad \text{AC} = \frac{(2{,}800{,}000 - 280{,}000) \times 0.08}{1.08^{30} - 1} + 2{,}800{,}000(0.08)$$

$$+312{,}000 = 558{,}745.13$$

Using the exact method, the same conclusion is reached—namely, to replace the old steam unit with electrically driven compressors.

6.5.3 Project Evaluation Criteria

Managers are often required to make choices among capital projects that may deliver benefits and may also consume resources on an annual basis over a number of periods. Several standard methods are used in industry to evaluate such projects (Eriona and Nguyen 2013). These include *net present value* (NPV), *internal rate of return* (IRR), *payback* (PB), and *profitability index* (PI).

1. *Net present value*

$$\text{NPV} = -P + \sum_{m=1}^{n} \frac{\text{NCIF}(m)}{(1+i)^m} + \frac{\text{CR}}{(1+i)^n} \tag{6.5}$$

$$m = 1 \text{ to } n$$

where:

NPV = Net present value (dollars)
P = Present investment made to initiate a project activity (dollars)
NCIF(m) = Net cash inflow (dollars) in the period m, which represents revenues earned minus costs incurred = ($R(m) - C(m)$) (dollars)
i = Cost of capital (interest) rate (fraction)
n = Number of interest period (year)
CR = Capital recovery (dollars), which is the amount regained at the end of the project through resale or other methods of disposition

Note that the first term on the right-hand side is the capital outlay for the project, or an outflow of value (cash). The second term on the right-hand side is the sum of discounted net cash inflow earned over the years. The third term on the right-hand side is the discounted capital recovery of the project.

One major weakness of the NPV equation is that all benefits derived from a project must be expressed in dollar equivalents—within NCIF(m)—in order to be included. Nonmonetary benefits, such as enhanced corporate image, expanded market share, and others, cannot be represented.

For the special case of NCIF(m) = CF = constant

$$\mathrm{NPV} = -P + \mathrm{CF}\frac{(1+i)^n - 1}{i \times (1+i)^n} + \frac{\mathrm{CR}}{(1+i)^n} \tag{6.6}$$

Projects with the largest NPV values are preferable, as NPV represents the net total value added (before tax) to the firm by the project at hand. Note that NPV may be determined only if the project's net cash inflow NCIF(m) is known.

2. *Internal rate of return*. Rate of return is generally defined as the earnings realized by a project in a percentage of its principal capital.

   The IRR is the average rate of return (usually annual) realized by a project in which the total net cash inflow is exactly balanced with its total net cash outflow, resulting in zero NPV value at the end of its project life cycle. In other words, this is the rate realizable when reinvestment of the project earnings is made at the same rate until maturity.

   IRR is determined by the following equations:

$$0 = -P + \sum_{m=1}^{n} \frac{\mathrm{NCIF}(m)}{(1+\mathrm{IRR})^m} + \frac{\mathrm{CR}}{(1+\mathrm{IRR})^n} \tag{6.7}$$

$$m = 1 \text{ to } n$$

   For NCIG(m) = CF = constant.

$$0 = -P + \mathrm{CF}\frac{(1+\mathrm{IRR})^n - 1}{\mathrm{IRR} \times (1+\mathrm{IRR})^n} + \frac{\mathrm{CR}}{(1+\mathrm{IRR})^n} \tag{6.8}$$

   The IRR values (before tax) of acceptable projects must be much greater than the firm's cost of capital. Projects with high IRR are preferable.

3. *Payback period*. The PB is defined as the number of years that the original capital investment for the project will take to be paid back by its annual earnings, or

$$\mathrm{PB} = \frac{P}{\mathrm{CF}} \tag{6.9}$$

where:

P = Capital investment
CF = Annual cash flow realized by the project

Cost reduction projects with small PBs (e.g., less than two years) are preferable.

4. *Profitability index*. PI is defined by the ratio

$$\mathrm{PI} = \frac{\text{Present value of all future benefits}}{\text{Initial investment}}$$

$$= \sum \frac{\mathrm{NCIF}(m)}{1+\mathrm{IRR}^{m}} P \tag{6.10}$$

Projects with large PI values are preferable.

Example 6.6

Your company is currently pursuing three cost reduction projects at the same time.

- Project A requires an investment of \$10 million. It is expected to yield a cost savings of \$30 million in the first year and another \$10 million in the second year.
- Project B demands an investment of \$5 million. It is expected to produce a cost savings of \$5 million in the first year and another \$20 million in the second year.
- Project C needs an investment of \$5 million. It is expected to bring about a cost savings of \$5 million in the first year and another \$15 million in the second year.

After the second year, there will be no receivable benefit or capital recovery from any of these projects. The cost of capital (interest rate) is 10% per year.

Determine the ranking of these projects on the basis of the evaluation criteria of NPV, IRR, PB, and PI.

Answer 6.6

Table 6.12 summarizes the results obtained:

P = Present investment
$n = 2$
CF = Cash flow
CR = Capital recovery = 0
$i = 10\%$

TABLE 6.12

Summary of Results

	Time ≥						
Project	**0**	**1**	**2**	**NPV**	**IRR (%)**	**PB**	**PI**
A	–10	30	10	25.5	230	0.5	3.55
B	–5	5	20	16	156	0.4	4.22
C	–5	5	15	12	130	0.5	3.39

NPV computation

1. NPV = − 10 + 30/1.1 + 10/1.1^2 = \$25.537
2. NPV = −5 + 5/1.1 + 20/1.1^2 = \$16.074
3. NPV = −5 + 5/1.1 + 20/1.1^2 = \$11.942

IRR

1. $0 = -10 + 30/(1 + r) + 10/(1 + r)^2$; $r = 2.3\%$
2. $0 = -5 + 5/(1 + r) + 20/(1 + r)^2$; $r = 1.56\%$
3. $0 = -5 + 5/(1 + r) + 15/(1 + r)^2$; $r = 1.3\%$

PB

1. PB = 10/[(30 + 10)/2] = 0.5 year
2. PB = 5/[(5 + 20)/2] = 0.4 year
3. PB = 5/[(5 + 15)/2] = 0.5 year

PI

1. PI = [3.0/1.1 + 10/1.1^2]/10 = 3.553
2. PI = [5/1.1 + 20/1.1^2]/5 = 4.214
3. PI = [5/1.1 + 15/1.1^2]/5 = 3.3884

6.6 Conclusions

This chapter reviews basic cost accounting issues related to product and service costing. Product/service costs have direct and indirect cost components. While direct costs are relatively easy to assess, the indirect costs that account for overhead charges related to facility, management, utilities, and others may need to be properly assessed by using tools such as ABC. This is especially true for the cases in which multiple products/services are produced and marketed to different customer groups each demanding special customization efforts, and the resulting overhead charge represents a significant percentage of the overall product/service costs. For enterprises with a single product/service and a minor amount of overhead charge relative to its total product/service cost, the traditional method of estimating the overhead charge is usually sufficient.

All production activities add value but create cost. ABC is a cost accounting method that redistributes indirect cost (incurred in producing product/service) in accordance with the specific production activities involved. Conducting an ABC cost study will not increase or decrease company profitability. However, when applied properly, the ABC method will generate cost-based insights, which could form a new basis for companies to take management action, such as changing the product/service mix, simplifying a specific production process, and/or revising pricing policies in order to more directly account for the activities needed to respond to customer demands. Company profits are expected to improve after such new management actions are effectively implemented.

Cost data may apply for a single period or for multiple periods. In the case of multiple periods, the time dependency of cost data must be considered, and the concept of the time value of money and the compound interest formulas are to be applied. Depreciation accounting affects the facility costs that are part of the indirect costs of products/services. Different depreciation methods will lead to more or less indirect costs for the products/services. Finally, the inventory costs are affected by the sequence in which products are introduced or withdrawn. As engineering economy foundation topics, all these concepts have been reviewed in the appendices.

Cost data may be uncertain because of factors related to the economy, market condition, political stability, labor movement, and others. For uncertain cost data, risk analysis may be needed. The Monte Carlo simulation is an efficacious method to conduct risk analyses. Several other methods are also available to account for cost uncertainties.

David Rockefeller said, "Success in business requires training, discipline and hard work. But, if you're not frightened by these things, the opportunities are just as great today as they ever were." ABC is an example of such value-adding opportunities, which were developed due to discipline and hard work.

Managers need to become well versed in cost accounting.

Questions

1. The company is evaluating two specific proposals to market a new product. The current interest rate is 10%.

   Proposal A calls for setting up an in-house manufacturing shop to make the product, requiring an investment of $500,000. The expected profits for the first to fifth years are $150,000, $200,000, $250,000, $150,000, and $100,000, respectively.

   Proposal B suggests that the manufacturing operation be outsourced by contracting an outside shop, requiring a front-end payment of $300,000. The expected profits for the first to fifth years are $50,000, $150,000, $200,000, $300,000, and $200,000, respectively. The expected profits would be lower in earlier years due to third-party markup.

   Which proposal should the company accept?

2. The company's warehouse has been busy taking in and shipping out vendor-supplied automotive parts. Table 6.13 shows the warehouse's activities in eight consecutive periods, during which time the price of the parts has steadily increased.

TABLE 6.13

FIFO and LIFO Computation

Period	Units In	Unit Price Paid ($)	Units Out
1	150	100	—
2	250	120	—
3	—	—	180
4	—	—	100
5	100	130	—
6	—	—	200
7	100	140	—
8	—	—	80

a. Determine the total LIFO prices for each stock withdrawal in periods 3, 4, 6, and 8.
b. Repeat the same price computation using the FIFO technique.

3. A dam is being considered on a river that periodically overflows. Each time the river overflows, it causes about \$600,000 in damages. The project horizon is 40 years. A 10% interest rate is being used.

   Three different designs are available, each with different costs and storage capacities (see Table 6.14).

   The U.S. weather service has provided a statistical analysis of annual rainfall in the area draining into the river (see Table 6.15).

   Assume that the dam requires no annual maintenance, has zero salvage value at the end of its 40-year life, and is essentially empty at the start of each annual rainfall season. Which design alternative would you choose?

4. The NPV equation (Equation 6.23) is described as follows:

$$\text{NPV} = -\text{P} + \sum_{m=1}^{n} \frac{C\ (m)}{(1+\text{i})^{m}} + \frac{\text{CR}}{(1+i)^{n}} \tag{6.23}$$

$$m = 1 \text{ to } n$$

The NPV equation is important for evaluating project-based investments. It is also a basic equation for defining the concept of "value addition," and has broad philosophical implications for what engineers do. Explain.

TABLE 6.14

Design Options

Design Alternatives	Cost (\$)	Maximum Storage Capacity (units)
A	500,000	1
B	625,000	1.5
C	900,000	2.0

TABLE 6.15

Annual Rainfall and Probability

Units Annual Rainfall	Probability
<0.1	0.1
0.1–0.5	0.6
0.6–1.0	0.15
1.1–1.5	0.1
1.6–2.0	0.04
2.0 or more	0.01

5. A manufacturing company makes three products, A, B, and C. The fixed FO is $60,000, consisting of $10,000 for material handling, material waste, and procurement; $30,000 for rent and utilities; and $20,000 for safety and canteen costs. Other costs are shown in Table 6.16.
   a. Determine the product cost for products A, B, and C, using the ABC method.
   b. If products A, B, and C are sold at $400, $350, and $150 per unit, respectively, what is the gross profit for each product?
   c. What is the company's total gross profit per month if all units produced are sold?
6. A company makes and sells three technology products: A, B, and C. It has a production plant with 17,000 square feet of floor area, consisting of machine setup (2000 square feet), machining operation (9000 square feet), assembly (4000 square feet), and inspection, packaging, and shipping activities (2000 square feet).

   The total annual expenditure for the plant is $200,000 for depreciation, $700,000 for utilities, $20,000 for phone and travel services, $150,000 for manufacturing supports, $200,000 for procurement, and $150,000 for supervision.

   The labor hours and material costs required to manufacture the products are shown in Table 6.17.

   The labor charges are $25 per hour for machine setup, $35 per hour for machining operation, $30 per hour for assembly, and $20 per hour for inspection, packing, and shipping.

   The company plans to sell Product A at $5000 per unit, Product B at $4,500 per unit, and Product C at $4,100 per unit. All products manufactured during the year

TABLE 6.16

Product Costs

	Product A	Product B	Product C
Number of units produced per month	250	400	900
Total material costs per month ($)	5000	8000	4000
Labor hours per unit	4	3.5	1.5
Labor rate per unit ($ per hour)	25	20	30
Machine hour per unit (hour)	1	1	3

TABLE 6.17

Manufacturing Costs for Three Products

	A	B	C
Machine setup (hours)	2	3	4
Machine operation (hours)	16	12	8
Assembly (hours)	4	3	2
Inspection/packing/shipment (hours)	2	2	2
Raw materials/unit of product ($)	950	430	640
Purchased components/unit of product ($)	100	80	90
Outsourced service/unit of product ($)	20	30	40
Number of units produced per year	700	900	550

are assumed to be sold successfully. Apply the activity-based costing technique to determine the product cost and individual gross margin for each product.

7. You are considering a good-looking Toyota hybrid car priced at $28,000 or an elegant GM luxury car at $24,000. The fuel efficiency is rated at 50 miles per gallon for the Toyota and 25 miles per gallon for the GM. The annual maintenance cost for both cars is about 0.5% of the car price. The gasoline in the local market is selling at $2.00 per gallon. The cars are to be driven about 10,000 miles per year. You plan to keep your car for five years only. At the end of the fifth year, the resale values of the Toyota and the GM are about 40% and 30%, respectively, of their original prices. The interest rate is 6%.

   Which car is the better choice from the standpoint of costs?

8. Company X manufactures automotive door panels that may be made of either sheet metal or plastic sheet molding (glass fiber-reinforced polymer). Sheet metal bends well to the high-volume stamping process and has a low material cost. Plastic sheet molding meets the required strength and corrosion resistance and has a lower weight. The plastic-forming process involves a chemical reaction and has a slower cycle time. Table 6.18 summarizes the cost components for each.

   Assuming that the machinery and tooling have no salvage value at the end of their respective equipment lives, what is the annual production volume that would make the plastic panel more economical?

   For production volume up to 536,156 panels per year, the plastic panels are more economical.

9. Company X produces two products, A and B. Table 6.19 summarizes the cost structures of these two products over a three-month period.

TABLE 6.18

Cost Components for Door Panels

Description	Plastic	Sheet Metal
Material cost ($ per panel)	5	2
DL cost ($ per hour)	40	40
FO ($ per year)	500,000	400,000
Maintenance expenses ($ per year)	100,000	80,000
Machinery investment ($)	3 million	25 million
Tooling investment ($)	1 million	4 million
Equipment life (years)	10	15
Cycle time (minutes per panel)	2	0.1
Interest rate (%)	6	6

TABLE 6.19

Cost Structures over Three Months

	Product A	Product B
Selling price ($ per unit)	10	12
Variable cost ($ per unit)	5	10
Fixed costs ($)	600	2,000
Machining time (hour per unit)	0.5	0.25

The company's manufacturing operation is limited to 30,000 machine hours available per a three-month period. Furthermore, because of a prior sales commitment, the company must produce at least 1000 units of Product B. Determine the maximum profit the company can achieve in a three-month period.

10. *Buffalo Best Company* markets three products for sale. Product A, Product B, and Product C. Its production plant, which is located in the city of Buffalo, occupies 20,000 square feet of space. The use of this space is carefully planned as follows:
    a. Product assembly: 5000 square feet
    b. Machine setup: 2500 square feet
    c. Machining operation: 10,000 square feet
    d. Inspection, packaging, and shipping: 2500 square feet

    This plant has an expenditure of
    a. $200,000 for supervision
    b. $250,000 for procurement
    c. $250,000 for depreciation
    d. $750,000 for utilities
    e. $25,000 for phones and travel expenses
    f. $175,000 for manufacturing supports

    Each of the three products that this company makes requires different labor hours and materials costs, as shown in Table 6.20.

    The labor charges of the company are as follows:

#	Type of Labor Hours	$/hour
1	Machine setup	$40.00
2	Machine operation	$50.00
3	Assembly	$35.00
4	Inspection/packing/shipping	$30.00

The company will sell the products at the prices shown in Table 6.21.

TABLE 6.20

Buffalo Best Company Operations Data

#	Requirements (per unit of products)	A	B	C
1	Machine setup (hours)	2	4	5
2	Machine operation (hours)	20	15	12
3	Assembly (hours)	5	4	3
4	Inspection/packing/shipment (hours)	3	3	3
5	Raw material ($)	1000	500	700
6	Purchased parts needed ($)	150	120	130
7	Purchased services ($)	30	40	50
8	Number of units produced per year (–)	800	1000	700

TABLE 6.21

Unit Prices

#	Products	Price/unit
1	Product A	$6000
2	Product B	$5000
3	Product C	$4000

All products made by the Buffalo Best Company are assumed to have successful sales rates.

a. Apply activity-based costing to determine the unit cost and the individual gross margin for each of Product A, B, and C. Show the detailed computations.

b. Which product has the highest gross margin percentage?

11. Monte Carlo simulations is a mathematical tool often used in engineering and business to solve complex problems involving uncertainties or risks.

    a. Explain the technological foundation of this tool?

    b. How can it be applied? Discuss the inputs to and outputs from Monte Carlo simulation applications.

    c. What specific benefits may be derived from applying this tool, in comparison with those that can be readily obtained from employing a deterministic model in cost estimation, such as using an Excel spreadsheet program?

12. Employee A is about to retire. Based on his long tenure with the company, he is entitled to use his unused sick leave to pay for health insurance upon retirement. His current sick leave benefit is estimated to be worth $3156 annually. The health insurance premium is estimated to be $2532 per year for family coverage and $588 for single coverage, and these rates are projected to increase by 3% per year into the future. He has two options.

    Option one is to take the full amount of $3156 now, which will continue during his lifetime. Afterwards, his spouse will need to pay for the single coverage premium out of her own pocket. He will receive no refund from the company, even though his sick leave benefit ($3156) exceeds the family coverage premium ($2532) initially.

    Option two is to take only 70% of the full amount ($2,209) during his lifetime, and this benefit is guaranteed to continue beyond his death to cover the health insurance premium for the spouse, should the spouse survive him.

    Currently, Employee A is 73 years old and has a life expectancy of 11 more years. His spouse is 70 and her life expectancy is 18 years. Assume the cost of money is 4%, which option is better for Employee A and his spouse?

Appendices

Appendix 6.A: Basic Terms in Cost Accounting

Managers need to become familiar with the standard vocabulary used by cost accountants or cost engineers, as costs are important elements for corporate performance evaluation, profitability analysis, and managerial decision-making. While the cost accounting systems used by various firms do not need to strictly follow the generally accepted accounting principles (GAPP) adopted by the financial accounting profession, company managers are still advised to understand the meaning of various accounting terms in order to ensure that their cost-based decisions are made properly. The following is a general set of accounting terms used by many firms (Smith 2014; Ryder Management Inc. 2014):

1. *Cost center*: An organizational unit that accomplishes well-defined functional objectives in support of others (e.g., R&D, procurement, finance, operations, legal services, and public relations). The operating budgets of cost centers are authorized by profit centers.
2. *Profit center*: An organizational unit whose functional objectives are related to the profitability generation in a company (e.g., business management, product design and development, engineering, marketing/sales, and customer services).
3. *Inventory costs*: The total sum of product costs, which are composed of the direct costs and indirect costs related to the manufacturing of the products/services involved.
4. *Direct costs*: Materials and labor costs associated with the manufacturing of a product/service.
5. *Indirect costs*: All overhead costs (e.g., rent, procurement, depreciation, supervision, supplies, and power) indirectly associated with the production of products/services involved.
6. *Fixed costs*: Costs that do not strictly vary with the volume of products/services involved, such as the general manager's salary, rent for the facility, machine depreciation charges, and local taxes.
7. *Variable costs*: Costs that vary in proportion to the volume of products/services involved, including, for example, material, labor, and utilities.
8. *Step function costs*: Costs that would experience a step change when a specific production volume is exceeded; for example, the factory rent that may change stepwise if new floor space must be added because of the increased production volume.
9. *Contribution margin*: The product price minus unit variable cost; the economic value contributed by selling one unit of product/service to defray the fixed cost already committed for the current production facility.
10. *Cost pool*: An organizational unit where costs incurred by its activities performed for specific products/services (or other cost targets) are accumulated for subsequent assignments.
11. *Cost drivers*: Bases used to allocate indirect costs to products/services. The production of products/services drives the consumption of resources, and the utilization of resources incurs costs. Examples include floor space, head counts, number of transactions, number of employees, labor hours, machine hours, number of setups, and material weight.
12. *Cost objects*: Targets (such as product, service, customers, etc.), to which indirect costs are to be allocated.
13. *Budget*: A quantitative expression in dollar value of a project or a plan of action. Examples include production budget, product design budget, engineering budget,

R&D budget, sales budget, marketing budget, and advertising budget. Typically, budgets are specified for a specific period of time (e.g., a month, a quarter, or a year).

14. *Standard costs*: Direct and indirect costs budgeted for products. The standard costs are defined by using estimations or historical costs.
15. *Variance*: The difference between standard costs and actual costs. Such variance could be the result of price variation, quantity change, technology advancement, and other factors. Conventionally, actual quantities are used when computing price variation to easily assess the procurement performance. On the other hand, the quantity-based variance is computed by using standard costs for an easy assessment of the production performance.
16. *Current costs*: Costs for the total efforts (e.g., physical efforts, raw materials, and service fees) that must be spent in order to carry out an activity or implement a plan. Current costs form a key basis for managerial decision-making.
17. *Opportunity costs*: The benefit of the second-best alternative that must be forgone because of a commitment made to the first alternative. For example, a STEM professional who quits a job paying $100,000 a year to pursue a three-semester MBA degree at a university incurs an opportunity cost at graduation of $150,000 plus an out-of-pocket cost of $90,000 for tuition fees. Opportunity costs are included in managerial decision-making, but are not included in any cost accounting system.
18. *Sunk costs*: Costs that have already been spent or incurred. Such costs are typically included in all cost accounting systems, but they are not considered in any management decision-making for the future.

Appendix 6.B: Cost Analysis

Managers perform variance analyses and study the reasons for the deviation of actual costs from standard costs. They issue periodic and systematic reports of their findings and take proper actions to improve the efficiency and effectiveness of the organizational units as related to cost control (Kemp 2015; McGuire 2015).

There are two major factors affecting cost analysis, namely, time and accuracy. For management decisions, cost analyses may be performed for a single time period or for multiple periods. Cost data may vary or may be uncertain.

1. *Single-period analysis*

   Single-period analysis applies primarily to a short period of time during which the costs involved remain essentially constant. The gross profit equation for a given product line is given by the following equation:

$$\text{Gross profit} = \text{Revenue} - \text{Costs}$$

$$\text{GP} = P \times N - (\text{FC} + \text{VC} \times N) \tag{6.11}$$

where:

P = Product price (dollars/unit)
N = Number of products sold during the period
FC = Fixed costs (dollars)
VC = Variable costs (dollars/unit)
GP = Gross profit (dollars)

For the case of breakeven (i.e., GP = 0), the break-even product quantity is given by

$$N^* = \mathrm{FC}/(P - \mathrm{VC}) \tag{6.12}$$

The value (P − VC) is defined as the contribution margin of the product. Selling each additional unit of a product/service generates a contribution in the amount of (P − VC) to defray the FC that has been committed to the production process.

Organizational performance can be readily assessed, as the number of cost items involved is limited. One needs to make sure that the values of these cost items are valid, although from time to time the validity of such values may be tough to verify precisely, if joint production activities and other cost-sharing business arrangements are involved.

2. *Multiple-period analyses*

   The cost analyses over a longer period of time (e.g., multiple periods) are much more difficult to calculate for two reasons. First, costs may change predictably over time due to inflation, investment return, cost of capital, and other reasons. Second, future events are unpredictable (e.g., natural disasters, labor unrest, political instability, war against terrorism, spread of disease, or investment climate) (Kinney and Raiborn 2012).

   The change of costs over time needs to be addressed by using concepts such as NPV and IRR. These concepts are built on the fundamentals of the time value of money, compound interest, and the cost of capital. These topics are introduced in Appendix 6.C. Depreciation accounting, an important part of the indirect costs of products, is included in Appendix 6.D.

   In dealing with the uncertainties of future costs, risks must be included in product cost analysis. Risk analysis is elucidated in detail in Section 6.4.

Appendix 6.C: Time Value of Money and Compound Interest Equations

The concept of time value of money refers to the notion that the value of money changes with time (Sullivan et al. 2014; Park 2012). This is because money at hand may lose value (purchasing power) if not invested properly. Money at hand may earn income through investment. A dollar that is to be received at a future date is not worth as much as a dollar that is on hand at the present. Thus, two equal dollar amounts at different points in time do not have equal value (purchasing power).

Before introducing basic compound interest equations useful for multiperiod cost analyses, a few definitions are reviewed next.

1. *Interest*: This represents a fraction of the principal designated as a reward (interest income) to its owner for having given up the right to use the principal. It may also be a charge (interest payment) to be paid by the borrower for having received the right to use the principal during a given interest period.
2. *Compound interest*: When the interest income earned in one interest period is added to the principal, the principal becomes larger for the next period. The enlarged principal earns additional interest income under such circumstances. The interest is said to have been compounding.

3. *Nominal interest rate*: The interest rate quoted by banks or other lenders on an annual basis, also called the *annual percentage rate* (APR).
4. *Effective interest rate*: The interest rate in effect for a given interest period (e.g., one month). For example, if the nominal interest rate for a bank loan is 12%, then its effective interest rate for each month is 1%.
5. *Nominal dollar*: The actual dollar value at a given point in time.
6. *Constant dollar*: The dollar value that has a constant purchasing power with respect to a given base year (e.g., the reference year 1995); the value is adjusted for inflation.
7. *Consumer price index*: The index tracked by the U.S. Department of Commerce to indicate the price change for a basket of consumer products (see Figure 6.A1). Since 1993, the inflation rate in the United State has been relatively low.

To introduce the compound interest formulas for multiple-period cost analyses, the following notations are used:

P = Present value (dollars), the value of a project, loan, or financial activity at the present time.

F = Future value (dollars), the value of a project, loan or financial activity at a future point in time.

i = Effective interest rate for a given period during which the interest is to be compounded (e.g., 1% per month).

A = Annuity (dollars), a series of payments paid out or received at the end of each interest period.

n = Number of interest period under consideration.

1. *Single payment compound amount factor*

$$F = P \times (1+i)^n \tag{6.13}$$

$$F/P = (1+i)^n = (F/P,\ i,\ n)$$

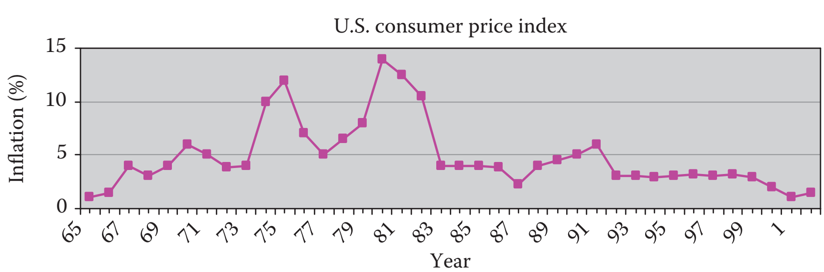

FIGURE 6.A1
Sample inflation rates in the United States.

Equation 6.13 defines the total value of an investment *P*, with periodical returns (i.e., interest income) added to the principals to earn more money at the end of *n* periods. Its derivation is shown in Appendix 6.F.

Example 6.7

Mr. Jones invests $5000 at 8.6% interest compounded semiannually. What will be the approximate value of his investment at the end of 10 years?

Answer 6.7

$$F = P(1+i)^n = 5000\left(1+\frac{0.086}{2}\right)^{20} = \$11{,}605.29$$

2. *Present worth factor*

$$P = \frac{F}{(1+i)^n} \tag{6.14}$$

$$\frac{P}{F} = (1+i)^{-n} = \left(\frac{P}{F}, i, n\right)$$

Equation 6.14 defines the present value of a sum that will be available in the future. The factor $(1 + i)^{-n}$ is also called the discount factor.

3. *Uniform series compound amount factor*

$$F = A \times \frac{\left[(1+\mathrm{i})^n - 1\right]}{i} \tag{6.15}$$

$$\frac{F}{A} = \frac{(1+i)^n - 1}{i} = \left(\frac{F}{A}, i, n\right)$$

Equation 6.15 determines the total future value of an account (e.g., retirement or college education) at the end of *n* periods, if a known annuity *A* is deposited into the account at the end of every period. Its derivation is shown in Appendix 6.G.

4. *Uniform series sinking fund factor*

$$A = F \times \frac{i}{(1+i)^n - 1} \tag{6.16}$$

$$\frac{A}{F} = \frac{i}{(1+i)^n - 1} = \left(\frac{A}{F}, i, n\right)$$

Equation 6.16 calculates the amount of the required annuity (e.g., a series of period-end payments) that must be periodically deposited into an account in order to reach a desired total future sum F at the end of n periods.

5. *Uniform series capital recovery factor*

$$A = P\frac{i\times(1+i)^n}{(1+i)^n-1} \tag{6.17}$$

$$\frac{A}{P} = \frac{i\times(1+i)^n}{(1+i)^n-1} = \left(\frac{A}{P}, i, n\right)$$

Equation 6.17 defines the amount of periodical withdrawal that can be made over n periods from an account worth P at the present time, such that the account will be completely depleted at the end of n periods.

Example 6.8

Mr. Jones wishes to establish a fund for his newborn child's college education. The fund pays $60,000 on the child's 18th, 19th, 20th, and 21st birthdays. The fund will be set up by the deposit of a fixed sum on the child's 1st through 17th birthdays. The fund earns 6% annual interest. What is the required annual deposit?

Answer 6.8

The future sum of a series of annual deposits is

$$F_1 = A_1\frac{1.060^{17}-1}{0.06} = 28.21288A_1$$

Annual withdrawal when the child enters college is.

$$A_2 = P_2\frac{0.06(1.06)^4}{(1.06)^4-1} = 0.2885915P_2$$

$$A_2 = 60{,}000$$

$$P_2 = F_1$$

Answer: A_1 = $7369.20 (the required annual deposit).

6. *Uniform series present worth factor*

$$P = A\frac{(1+i)^n-1}{i\times(1+i)^n} \tag{6.18}$$

$$\frac{P}{A} = \frac{(1+i)^n-1}{i\times(1+i)^n} = \left(\frac{P}{A}, i, n\right)$$

Equation 6.18 determines the total present value of an account to which an annuity A is deposited at the end of each period. For example, if A is the periodical maintenance costs for capital equipment, then this equation calculates the present value of all maintenance costs over its product life of n periods.

Example 6.9

The annual maintenance on the parking lot is $5000. What expenditure would be justified for resurfacing if no maintenance is required for the first five years, $2000 per year for the next 10 years, and $5000 a year thereafter? Assume the cost of money is 6%.

Answer 6.9

Since the annual maintenance cost is the same after 15 years, the effect of resurfacing applies to the first 15 years only. The total present value of the "doing nothing" option is

$$P_1 = A\frac{(1+i)^n - 1}{i(1+i)^n}$$

$$= 5000\frac{1.06^{15} - 1}{0.06(1.06^{15})} = \$48,561.25$$

The total present value of the resurfacing option is

$$P_2 = P + 2000\frac{1.06^{10} - 1}{0.06 \times 1.06^{10}(1.06)^5}$$

$$= P + 10,999.77$$

Setting $P_1 = P_2$

$$P = 37,561.47\,(\text{the maximum amount for resurfacing the parking lot})$$

Example 6.10

You need a new Microsoft Surface 3 laptop computer and find one on sale for $3900 cash, or $500 down and $200 monthly payments for two years. What nominal annual interest does the vendor charge you, if you elect to use its time-payment plan?

Answer 6.10

$$P = 3900 - 500 = \$3400 \ (\text{loan amount})$$

$$A = \$200$$

$$P = A\frac{(1+i)^n - 1}{i(1+i)^n}$$

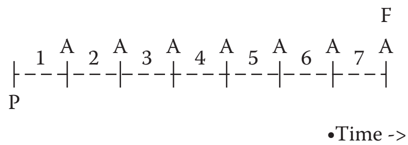

FIGURE 6.A2
Time line convention.

$$3400 = 200\frac{(1+i)^{24} - 1}{i(1+i)^{24}}$$

This is an implicit equation for the single unknown *i*. It may be solved by trial and error: Input a trial value of *i*, and compute residual (Delta = RHS − LHS). The *i* value that produces zero (Delta) is the answer:

Trial Value of *i*	Delta
0.06	4.496
0.03	0.0645
0.025	−0.884986
0.029	−1194
0.02965	0.0004288

Answer: Monthly rate = 2.965% and the nominal annual rate is 35.58%.

For all multiple-period problems, the time line convention is regarded as standard (see Figure 6.A2).

When applying these compound interest formulas, the following guidelines should be kept in mind:

a. **P** is at present, **F** is at a future point in time, and **A** occurs at the end of each period.
b. The periods must be consecutively and sequentially linked with the end of one and the beginning of the next.
c. Complex problems may be broken down into time segments so that the equations may be correctly applied to each of the segments.

Appendix 6.D: Depreciation Accounting

In calculating indirect costs associated with production facility, equipment, and other tangible assets related to production, depreciation charges must be included. Depreciation is a cost-allocation procedure whereby the cost of a long-lived asset is recognized in each accounting period over the asset's useful life in proportion to its benefit brought forth over the same period. This procedure is undertaken in a reasonable and orderly fashion. Specifically, the acquisition cost of an asset can be considered as the price paid for a series of future benefits. As the asset is partially used up in each accounting period, a corresponding portion of the original investment in the asset is treated as the cost incurred for the partial benefit delivered.

Three specific depreciation accounting methods are generally accepted in industry. They are discussed next, using the following notations:

P	= Initial investment (dollars) at the present time.
N	= Useful life of a long-lived asset measured in years (e.g., $N = 25$ for buildings, $N = 15$ for equipment, $N = 5$ for automobiles, and $N = 3$ for computers).
$D(m)$	= Depreciation charge (dollars) in the asset's m(th) year.
L	= Salvage value (dollars) recoverable at the end of the equipment's useful life.
$AD(m)$	= Accumulated depreciation (dollars), which is the total amount of depreciation charges accumulated at the end of the m(th) year.
$BV(m)$	= Book value (dollars) of an asset in its m(th) year. $BV(m) = P - AD(m)$
$P - L$	= Depreciation base (dollars).
$r(m)$	= Depreciation rate, a fraction of the depreciable base to be depreciated per year.

1. *Straight line*

   By this depreciation method, an equal portion of depreciation base ($P - L$) is designated as the depreciation charge for each period of the assets' estimated useful life:

$$D(m) = \frac{P - L}{N} = \text{constant} \tag{6.19}$$

$$BV(m) = P - m \times \frac{P - L}{N}; \quad m = 1, 2, 3, \ldots$$

$$r(m) = \frac{1}{N} = \text{constant}$$

$$AD(m) = m(P - L)/N$$

   More than 91% of publicly traded companies in the United States use this straight-line depreciation method.

2. *Declining balance*

   By this depreciation method, the depreciation charge is set to equal to the net book value (e.g., acquisition cost minus accumulated depreciation) at the beginning of each period (e.g., year) multiplied by a fixed percentage. If this percentage is two times the straight-line depreciation percentage, then it is called a double-declining balance method:

$$D(m) = P \times r \times (1 - r)^{(m-1)} \tag{6.20}$$

$$BV(m) = P(1 - r)^m$$

$$r(m) = \text{constant}; \quad r = \frac{2}{N}\ (\text{double-declining balance method})$$

$$AD(m) = P \times \left[1 - (1 - r)^m\right]$$

Note that the salvage value is not subtracted from the acquisition cost. To make sure that the total accumulated depreciation does not exceed the depreciation base, the depreciation charge of the very last period (e.g., year) must be manually adjusted.

3. *Units of production method*

   This method prescribes that the depreciation charge is assumed to be proportional to the service performed (e.g., units produced or hours consumed). Companies that are involved with natural resources (e.g., oil and gas exploration) use the units of production method to depreciate their production assets. Software companies also use this method to depreciate their capitalized software development costs.

Example 6.11

The company plans to change its depreciation accounting from the straight-line method to the double-declining method on a class of assets that have a first cost (acquisition cost) of \$80,000, an expected life of six years, and no salvage value. If the company's tax rate is 50%, what is the present value of this change, assuming 10% interest compounded annually?

Answer 6.11

$$P = 80{,}000;\quad N = 6;\quad t = 0.5;\quad L = 0$$

$$F = (1 - t)\text{ Delta};\quad P = F(1+i)^{-N};\quad I = 10\%$$

Table 6.A1 shows the present values of the differences between these two depreciation charges for the assets' expected life of 6 years.

Answer = \$2,191.72.

Example 6.12

A new delivery truck costs \$40,000 and is to be operated approximately the same amount each year. If annual maintenance costs are \$1,000 the first year and increase \$1,000 each succeeding year and, if the truck trade-in value is \$24,000 the first year and decreases

TABLE 6.A1

Calculation of Difference due to Depreciation Methods

Year	SL	Double Declining	Delta	$F = (1 - t)$Delta	Present Worth
		r = 2 (1/6) = 0.333333			
1	13333.33	2.6666.67	13333.34	6666.67	6060.61
2	13333.33	17778.66	4445.33	2222.66	1836.91
3	13333.33	11851.87	−1481.46	−740.73	−556.52
4	13333.33	7901.25	−5432.08	−2716.04	−1855.09
5	13333.33	5267.5	−8065.83	−4032.92	−2504.12
6	13333.33	10534.05	−2799.28	−1399.64	−790.06
			Total		2191.72

uniformly by $3,000 each year thereafter, at the end of which year will the costs per year of ownership and maintenance be at a minimum?

Answer 6.12

The average annual ownership cost is calculated as shown in Table 6.A2.

The numbers in the sixth column are produced by dividing the numbers in the fifth column by the ownership duration in years. Answer: Fifth year.

Example 6.13

Ceramic hot-gas filters provide 2400 hour of service life. Three of the processes in a refinery are each equipped with one of these filter sets. Each filter set has an initial cost of $1200. When production is scheduled, each process runs 24 hours per day.

In the first quarter of the year, Process A did not start operating until the beginning of the fourth week. Process B terminated at the end of the 10th week. Process C was on stream for the entire period. What depreciation charge should be allocated for ceramic filters during the first quarter?

Answer 6.13

The proper method of calculating the depreciation charge is on the basis of usage, as shown in Table 6.A3.

TABLE 6.A2

Annual Ownership Cost Computation

Year	Annual Maintenance Cost	Trade-In Value	Accumulated Depreciation	Total Accumulated Cost of Ownership	Average Annual Cost over the Ownership Period
1	1000	24,000	16,000	17,000	17,000
2	2000	21,000	19,000	22,000	11,000
3	3000	18,000	22,000	28,000	9,333
4	4000	15,000	25,000	35,000	8,750
5	5000	12,000	28,000	43,000	8,600
6	6000	9,000	31,000	52,000	8,667

TABLE 6.A3

Depreciation Based on Usage

	A	B	C
Cost ($)	1200	1200	1200
Weeks in operation	10	10	13
Hours in operation	1680	1680	2184
Percentage of useful life	70	70	91
Depreciation charge ($)	840	840	1092
Total = $2720 (zero-salvage value assumed)			

Appendix 6.E: Inventory Accounting

After the direct and indirect costs are estimated, the product costs can be defined. When products are transferred from WIP operations to an FG warehouse, they become inventory. Inventory may be managed by one of two methods: first in and first out (FIFO) and last in and first out (LIFO). The FIFO method specifies that inventory that enters the warehouse first will leave the warehouse first. By the LIFO method, the inventory that enters the warehouse last is shipped out first (Bragg 2013).

According to the time value of money concept, these two inventory operational methods may yield different CGS. The inventory accounting takes into account such a possible change of product cost over time, due, possibly, to inflation. In general, companies utilize one of the following three inventory accounting methods:

1. FIFO (first in and first out)
2. LIFO (last in and first out)
3. Weighted average

LIFO is most useful during periods of high inflation, as it results in less reportable earnings with lower payable taxes to report; LIFO is not useful, however, when prices for raw materials decrease. LIFO also provides lower inventory value, thus understating the value of the inventory in the company's balance sheet. Finally, LIFO is a more conservative accounting technique than FIFO. Note that LIFO is prohibited by law in some countries, such as the United Kingdom, France, and Australia.

As a product of creative accounting, FIFO defines an inventory value more closely matched with its market value (Table 6.A4). It tends to make the income statement look better than it really is. In periods when the business climate experiences stagnation or recession, innumerable companies frequently switch from LIFO to FIFO. The weighted average method represents a compromise between the two (Table 6.A5).

Table 6.A6 is an illustration of the use of FIFO and LIFO accounting techniques. Assume that a manufacturing company has five units of products in inventory and each has a product cost of $100. Furthermore, the company produces five more units at $200 each in one period and then another five units at $300 each in a later period. During these periods, the company sells 10 units to customers. Determine the average CGS on the basis of both FIFO and LIFO and assess its impact on the company's net income.

TABLE 6.A4

FIFO Withdrawal

Period	Inventory	FIFO Withdrawal	Value
3	150 @ 100		
	250 @ 120		
		150 @ 100 + 30 @ 120	$18,600
4	220 @ 120		
		100 @ 120	$12,000
6	120 @ 120		
	100 @ 130		
		120 @ 120 + 80 @ 130	$24,800
8	20 @ 130		
	100 @ 140		
		20 @ 130 + 60 @ 140	$11,000

TABLE 6.A5

LIFO Withdrawal

Period	Inventory	LIFO Withdrawal	Value
3	150 @ 100		
	250 @ 120		
		180 @ 120	$21,600
4	150 @ 100		
	70 @ 120		
		70 @ 120 + 30 @ 100	$11,400
6	120 @ 120		
	100 @ 130		
		100 @ 130 + 100 @ 100	$23,000
8	20 @ 100		
	100 @ 140		
		80 @ 140	$11,200

TABLE 6.A6

FIFO and LIFO Inventory Accounting

	FIFO ($)	LIFO ($)	Weighted Average ($)	
(1) Beginning inventory				
5 × 100	500	500	500	Withdrawal of 10 units
(2) Purchasing and value added				5 × 100
5 × 200	1000	1000	1000	5 × 200
				5 × 300
5 × 300	1500	1500	1500	
(3) Ending inventory				
5 × ….	1500	500	1000	
(4) Cost of goods sold	1500	2500	2000	

The impact of inventory accounting on net income is quite direct, as illustrated in Table 6.A7. Table 6.A7 is an abbreviated income statement (see Section 7.4.1) wherein CGS is the costs of goods sold, GS&A is general, sales and administration expenses, and EBIT is earnings before interests and taxes. On switching from FIFO to LIFO inventory accounting, the tax liabilities are shown to have been reduced from $2.4 million to $2.0 million (Tables 6.A8 through 6.12).

Appendix 6.F: Derivation of Single Payment Compound Amount Factor

$$F_1 = P + P \times i = P(1+i) \text{ at the end of the first year}$$

$$F_2 = F_1 + F_1\, i = P(1+I)^2 \text{ at the end of the second year}$$

$$F_n = P(1+i)^n \text{ at the end of the } n\text{th year}$$

Hence, $F = P(1 + i)^n$ (Equation 6.13) and $P = F(1 + i)^{-n}$ (Equation 6.14).

TABLE 6.A7

Effect of Inventory Accounting on Net Income

	FIFO ($)	LIFO ($)	Weighted average ($)
Sales	10,000	10,000	10,000
CGS	1,500	2,500	2000
Gross margin	8,500	7,500	8,000
GS&A	2,000	2,000	2,000
EBIT	6,500	5,500	6,000
Interest	500	500	500
Taxable amount	6,000	5000	5,500
Tax (40%)	2,400	2,000	2,200
Net income	3,600	3,000	3,300

TABLE 6.A8

Product Costs

	Product A	Product B	Product C
Materials cost	20	20	4.44
Labor cost	100	70	45
Material handling and others	11.76	11.76	2.61
Rent	9.68	9.68	9.68
Utilities	4.48	4.48	13.43
Safety and canteen cost	21.33	18.66	8
Total product cost per unit	167.25	134.58	83.16

TABLE 6.A9

Operational Data

	Product A	Product B	Product C	Labor Rate/ Hour
Machine setup (hours)	2	3	4	$25
Machine operation (hours)	16	12	8	$35
Assembly (hours)	4	3	2	$20
Inspection/pack/ship (hours)	2	2	2	—
Raw materials/unit	$950	$430	$640	—
Purchased components/unit	$100	$80	$90	—
Outsourced services/unit	$20	$30	$40	—
Number of products made/year	700	900	550	—
Total labor hours per unit	24	20	16	—
Total material cost per unit	$1700	$540	$770	—

TABLE 6.A10

ABC Analysis of Problem 6.6

	Area	Percentage	Depreciation Fraction	Product A	Product B	Product C	Basis of Cost Allocation
1. Depreciation	$200,000						
Setup	2000	11.76%	23,529.41	7.47	11.2	14.94	Setup hours
Operation	9000	52.94%	105,882.35	64.17	48.13	32.09	Operation hours
Assembly	4000	23.53%	47,058.82	28.52	21.39	14.26	Assembly hours
Inspection	2000	11.76%	23,529.41	10.94	10.94	10.94	Inspection hours
Total	17000		$200,000	111.11	91.67	72.23	
2. Utilities	$700,000						
Utilities per unit				424.24	318.18	212.12	Operating hours
3. Labor							
Labor cost per unit				$770	$625	$480	Labor hours
4. Manufacturing support	$150,000						
Manufacturing support per unit				82.57	68.81	55.05	Production hours/unit
5. Supervision	$150,000						
Supervision per unit				82.57	68.81	55.05	Production hours/unit
6. Procurement	$200,000						
Procurement per unit				$129.03	$65.12	$92.85	Materials cost per unit
7. Phone and travel	$20,000						
Phone and travel per unit				9.3	9.3	9.3	

8. Summary of unit product cost					
Unit product cost	Raw materials		$950	$430	$640
	Purchased components		$100	$80	$90
	Outsourced service		$20	$30	$40
	Depreciation		111.11	91.67	72.23
	Utilities		424.24	318.18	212.12
	Labor cost		$770	$625	$480
	Manufacturing support		82.57	68.81	55.05
	Supervision		82.57	68.81	55.05
	Procurement		$129.03	$65.12	$92.85
	Phone + travel		9.3	9.3	9.3
	Total product cost/unit		$2,679	$1,787	$1,747
9. Gross margin	Price/unit		$5,000	$4,500	$4,100
	Gross margin		$2,321	$2,713	$2,353
	Gross margin%		46.42%	60.29%	57.40%
	Total gross margin	$5,361,000			

Note: Strategic decision may be made in favor of Product B, which has the high gross margin percentage. Note the following comments:

(1) Total overhead costs are $1,420,000 (= 200,000 + 700,000 + 20,000 + 15,000 + 200,000 + 150,000)

(2) Total material costs are $1,650,000 (= 700 (950 + 100 + 20) + 900 (430 + 80 + 30) + 550 (640 + 90 + 40))

(3) Total labor costs are $1,365,500 (= 700(2 * 25 + 16 * 35 + 4 * 30 + 2 * 20) + 900 (3 * 25 + 12 * 35 + 3 * 30 + 2 * 20) + 550(4 * 25 + 8 * 35 + 2 * 30 + 2 * 20))

(4) Sum of all cost is $4,444,400

ABS is to redistribute the overhead costs to various products. After redistribution, the total cost should be exactly equal to $4,444,400, no more and no less.

The product costs for A, B, and C are $2679, $1787, and $1747, respectively. The individual gross margins for A, B, and C are $2321, $2713, and $2553, respectively.

TABLE 6.A11

ABC Solutions to Buffalo Best Company Problems

		Area	Percentage	Depreciation Fraction	Product A	Product B	Product C	Basis of Cost Allocation
1. Number of products				800	1000	700		
2. Depreciation		$250,000						
	Setup	2500	12.50%	31,250.00	7.1	11.36	20.29	Setup hours
	Operation	10,000	50.00%	125,000.00	66.49	39.89	45.59	Operation hours
	Assembly	5000	25.00%	62,500.00	32.55	20.83	22.32	Assembly hours
	Inspection	2500	12.50%	31,250.00	13.02	10.42	14.88	Inspection hours
	Total	20,000		$250,000	119.16	82.51	103.09	
3. Utilities		$750,000						
	Utilities/unit				$319.15	$239.36	$273.56	Operating hours
4. Labor								
	Labor cost/unit				$1,345	$1,140	$995	Labor hours
5. Manufacturing support		$175,000						
	Manuf. support/unit				$83.07	$57.59	$72.78	Production hours/unit
6. Supervision		$200,000						
	Supervision/unit				$94.94	$65.82	$83.18	Production hours/unit

7. Procurement	$250,000					
	Procurement/unit		$142.05	$56.82	$113.64	Materials cost per unit
8. Phone and travel	$25,000					
	Phone & travel/unit		$10.00	$10.00	$10.00	
9. Summary	Unit product cost	Raw materials	$1,000	$500	$700	
		Purchased parts	$150	$120	$130	
		Purchased service	$30	$40	$50	
		Depreciation	119.16	82.51	103.09	
		Utilities	$319.15	$239.36	$273.56	
		Labor cost	$1,345	$1,140	$995	
		Manufacturing support	$83.07	$57.59	$72.78	
		Supervision	$94.94	$65.82	$83.18	
		Procurement	$142.05	$56.82	$113.64	
		Phone + travel	$10.00	$10.00	$10.00	
		Total Product Cost/Unit	$3,293	$2,312	$2,531	
10. Gross margin		Price/unit	$6,000	$5,000	$4,000	
		Gross margin	$2,707	$2,688	$1,469	
		Gross margin%	45.11%	53.76%	36.72%	

TABLE 6.A12

Detailed Analysis of Problem 6.12

Price escalation = 3%												
Interest rate = 0.04												
Life expectancy:	A = 11		B = 18									
Year	1	2	3	4	5	6	7	8	9	10	11	12
Premium (family)	2532	2607.96	2686.2	2766.78	2849.79	2935.28	3023.34	3114.04	3207.46	3303.69	3402.8	3504.88
Premium (single)	588	605.64	623.81	642.52	661.8	681.65	702.1	723.17	744.86	767.21	790.22	813.93
Option 1 (100%)	3156	0	0	0	0	0	0	0	51.46	147.69	246.8	813.93
Discount factor		1.04	1.0816	1.12486	1.16986	1.216653	1.265319	1.31593	1.36857	1.42331	1.48024	1.53945
Present values (1)		0	0	0	0	0	0	0	37.6	103.76	166.73	528.71
Total present value (1)		3904.02		(Option 1)								
Option 2	2209.2	398.76	477	557.58	640.59	726.08	814.14	904.84	998.26	1094.49	1193.6	0
Present value (2)		383.42	441.01	495.69	547.58	596.79	643.43	687.6	729.42	768.97	806.35	
Total present value (2)		6100.26		(Option 2)								

Note: Option 1 (lower total cost in present value) is to be preferred.

Appendix 6.G: Derivation of Uniform Series Compound Amount Factor

$$F_1 = A$$

$$F_2 = F_1 + F_1 \times i + A = A + A \times i + A = A(1+i) + A$$

$$\ldots$$

$$F_n = A(1+i)^{n-1} + A(1+i)^{n-2} + \cdots + A(1+i) + A$$

$$F_{(n+1)} = A(1+i)^n + A(1+i)^{(n-1)} + \cdots + A$$

Form a difference between the last two series:

$$F_{(n+1)} - F_n = A(1+i)^n$$

On the other hand, by definition,

$$F_{(n+1)} = F_n(1+i) + A$$

Hence,

$$F_n \times i = A\left[(1+i)^n - 1\right]$$

$$F_n = F = A\,\frac{\left[(1+i)^n - 1\right]}{i}\ \text{(Equation 6.5.)}$$

The other three factors (i.e., Equations 6.16 through 6.18) are derived by substitution.

Appendix 6.H: Derivation of Annual Cost Computation Equations

There are two methods to compute the annual cost: the exact method and the approximate method.

1. *Exact method (depreciation based on sinking fund method)*

$$\text{AC} = \frac{(P-L)i}{(1+i)^n - 1} + Pi + \text{AE} \tag{6.21}$$

   The first term on the right-hand side is the annual cost (based on the sinking fund depreciation method) for the $(P - L)$ amount. The second term is the annual interest charge for the investment capital P. The last term is the annual expense.

2. *Approximate method (depreciation based on straight-line method)*

$$\text{AC} = \frac{(P-L)}{n} + (P-L)i\,\frac{(n+1)}{2n} + Li + \text{AE} \tag{6.22}$$

The first term on the right is the depreciation charge based on straight-line method. The second two terms on the right are the *average annual interest charge*, which is an opportunity cost (lost interest income for having made the investment). This average annual interest charge may be derived as follows:

The interest charge for each year is

Year	Formula
1	$= Pi = (P-L)i + Li$
2	$= \left[(P-L) - \frac{(P-L)}{n}\right] i + Li$
3	$= \left[(P-L) - \frac{2(P-L)}{n}\right] i + Li$
$\vdots$	$\vdots$
n	$= \left[(P-L) - (P-L)(n-1)/n\right] I + Li$

The sum of the total annual interest charge from Year 1 to Year n is

$$\begin{aligned}\text{Sum} &= i(P-L)n + (1-1/n) + (1-2/n) + \cdots + (1-(n-1)/n) + n\ L\ i \\ &= i(P-L)(n+1)/2 + n\ L\ i\end{aligned}$$

Thus, the average annual interest charge is (second two terms on the right side in Equation 6.22):

$$\text{AAIC} = \frac{\text{Sum}}{n} = i(P-L)\frac{(n+1)}{2n} + Li$$

Because of this last averaging step, this method is called an "approximate method."

Appendix 6.I: Conversion of a Probability Density Function to its Cumulative Distribution Function

The process of converting a probability density function to its cumulative distribution function is straightforward and unique. Figure 6.A3 shows a Triangular probability density function for the cost of the component C1. The vertical axis represents probability, and the horizontal axis represents cost. The Triangular probability density function is the easiest one to apply when a three-point estimate for a risky input variable is known.

The component C1 is assumed to have a minimum cost of \$30 (Point A), a maximum cost of \$80 (Point Z), and a most likely cost of \$50 (Point M). The area underneath the Triangular probability density function is normalized to 1; this condition prescribes that the y coordinate for the point N is 0.04 based on the calculation of $1 = 0.04 \times 0.5 \times (80 - 30)$.

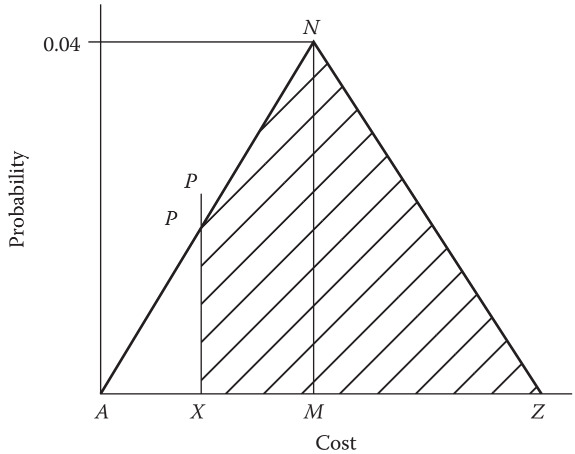

FIGURE 6.A3
A triangular probability density function for the cost of the component C1.

Let us insert a vertical cost line through x. With this cost line in place, we define the shaded area PNZXP as A_x, which is under the probability density function, but bound by the vertical cost line that passes through x on the left. We form a ratio of A_x to the total area APNZXA underneath the same probability density function. This ratio is designated as P_x. The value of P_x varies from 0 to 1, as x moves from Z to M and then to A. P_x is the probability for the cost of this component to be equal to or in excess of x. The pair of P_x and x represents a point in a cumulative distribution chart.

For another cost value, y, this process is repeated. A new pair of P_y and y defines another point in the descending cumulative distribution chart. After many repetitions, a descending cumulative curve is generated that resembles the one shown in Figure 6.A4. The vertical axis is the probability for the component cost to equal or exceed the value shown on the x axis. The x axis spans the minimum value of A on the left to the maximum value of Z on the right.

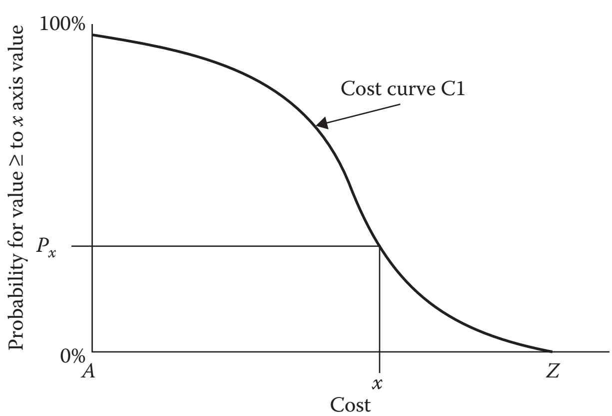

FIGURE 6.A4
A descending cumulative curve.

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7

Financial Accounting and Management for Engineering Managers

7.1 Introduction

Financial accounting and management serve the important corporate functions of reporting and evaluating the financial health of a firm (Williams et al. 2014; Libby et al. 2013; Weygandt et al. 2013).

Financial statements are prepared by certified management accountants (CMAs) and certified public accountants (CPAs), according to the Generally Accepted Accounting Principles (GAAP) in a conservative, material, and consistent manner. These financial documents provide (a) internal reporting to corporate insiders for planning and controlling routine operations and for decisions on capital investments and (b) external reporting to shareholders and potential investors in financial markets (Phillips 2012).

All financial statements are designed to be relevant, reliable, comparable, and consistent. Financial accounting treats owners (shareholders) and corporations as separate entities. Owners of corporations are liable only to the extent of their committed investments. Owners enjoy a flexible tenure and participation. As investors, they may buy or sell stocks of the company at any time. On the other hand, corporations are legal entities, fully responsible for their liabilities up to the limits of their total assets. Corporations are assumed to be going concerns and in operation forever, unless they cease to exist by declaring bankruptcy or being acquired by others.

This chapter discusses (a) language and concepts, (b) financial statements, (c) performance ratios and analysis, and (d) balanced scorecards or tools to monitor and promote corporate productivity. In Appendix 7.A, T-accounts are presented.

To be effective, science, technology, engineering, and math (STEM) professionals must know how to read financial statements; monitor the firm's activity, performance, profitability, and market position; and assess the financial health of a firm. Doing so will allow them to initiate proper projects (e.g., plant expansion, new product and technology development, new technology acquisition, strategic alliances) at the right time to add value to their employers.

7.2 Financial Accounting Principles

As practiced in many countries, all financial statements are formulated for a specific accounting period. A typical accounting period is three months. Specifically, the U.S.

Securities and Exchange Commission prescribes that all publicly traded companies file Form 10-Q reports every quarter. All companies also need to publish their Form 10-K reports annually. The financial statements must adhere to the basic principles of accounting, discussed in the following subsections (Weygandt 2013; Needles and Powers 2013).

7.2.1 Accrual Principle

Accounting statements include both cash and credit transactions. Revenue is recognized when it is earned. For example, a manufacturing enterprise will recognize revenues as soon as products are shipped to the customer and an invoice is sent, irrespective of any credit payment already received or yet to be collected. Sports teams are known to sell season tickets ahead of the games for cash and then recognize the applicable revenue only after each game is played. According to the accrual principle of accounting, companies recognize revenues when earned, with the assumption that the collection of this revenue from approved credit accounts and the delivery of the promised products or services are both reasonably ensured.

Similarly, the accrual principle specifies that costs and expenses are established when incurred, even before actual payments are made.

7.2.2 Matching

Expenses are recognized by matching them with the revenue generated in a given accounting period. For example, the cost of goods sold (CGS) is recognized as an expense only after products are sold and revenue is recognized. Before the products are sold, the CGS stays as inventory—a part of the corporate current assets (CA)—even though costs for materials, labor, and factory overhead have already been spent for these unsold products.

7.2.3 Dual Aspects

The assets of a company are always equal to the claims against it (i.e., assets equal to claims). The claims originate from both creditors and owners. Each transaction has a dual effect in that it induces two entries in order to maintain a balance between assets and claims.

7.2.4 Full Disclosure Principle

All relevant information is disclosed to the users of the company's financial reports. Extensive footnotes contained in the annual reports of numerous publicly traded companies are testimonials for such disclosure practices.

7.2.5 Conservatism

Assets are to be recorded at the lowest value consistent with objectivity (e.g., book values of certain corporate fixed assets are often lower than market values). While profits are not recorded till recognized, losses are recorded as soon as they become known. Inventories are valued at the recorded cost or market value, whichever is lower.

7.2.6 Going Concern

As stated in Section 7.1, it is assumed that the company's business will go on forever. This assumption justifies the current practice of using historical data (e.g., the original acquisition costs) and a reasonable method of depreciation (e.g., straight line) by which the book value of corporate tangible assets is defined. Otherwise, liquidation accounting must be applied to define the corporate asset value by using current market prices.

7.3 Key Financial Statements

Typically, companies use three financial statements: income statement, balance sheet, and funds flow statement (Fraser and Ormiston 2015; Tracy and Tracy 2014). They are described next.

7.3.1 Income Statement

The income statement is an accounting report that matches sales revenue with pertinent expenses that have been incurred (CGS, tax, interest, depreciation charges, salaries and wages, administrative expenses, R&D, etc.). Sometimes it is also called the profit or loss statement, earnings statement, or operating and revenue statement. The income statement contains the following key entries (Tracy 2014):

1. *Sales revenue* is the total revenue realized by the firm during an accounting period. Sales revenue is recognized when earned, for example, by having goods shipped and invoices issued.
2. *CGS* is the cost of goods that have been actually sold during an accounting period. In a manufacturing company, CGS is calculated as the opening inventory at the beginning of an accounting period, plus labor costs, material costs, and manufacturing overhead incurred during the period, and minus the closing inventory at the end of the period.
3. *Gross margin* is the sales revenue minus the CGS. The gross margin percentage is the ratio of gross margin divided by sales revenue.
4. *Expenses* are those expenditures chargeable against sales revenue during an accounting period. Examples include general, selling, and administrative expenses (GS&A); depreciation charges; R&D; advertising; interest payments for bonds; employee retirement benefit payments; and local taxes.
5. *Depreciation* is a process by which the cost of a fixed, long-lived asset is converted into expenses over its useful life. This is in proportion to the value it has produced during an accounting period (see Appendix 6.D).
6. *EBIT* is the earnings before interests and taxes.
7. *Net income* is the excess of sales revenue over all expenses (e.g., CGS, all items under (4), and corporate tax) in an accounting period. Sometimes it is also called profit, earnings, or net operating profit after tax (NOPAT).
8. *Dividend* is the amount per share paid out to stockholders in an accounting period.
9. *Earnings per share* are the net income of a firm during an accounting period (e.g., three months or a year), minus dividends on preferred stock, divided by the number of common shares outstanding.
10. *Costs* can be defined as follows: while all costs are also expenditures, not all costs are expenses. Only expenses are chargeable against revenues in a given accounting

period. For example, direct and indirect costs contained in the products preserved as inventory are not recognized immediately as expenses. When products in inventory are sold, the respective CGS is then recognized as expenses in the income statement, along with other expenses.

11. *Cash flow* is defined as *net income* plus noncash charges (such as depreciation). It represents the net inflow of cash to a company at the end of an accounting period.

    An income statement shows the firm's activity. An example is given in Table 7.1 for the XYZ Company. In general, sales revenue is referred to as the *top line* and net income as the *bottom line* figures. These line items are examined closely by financial analysts, as are the line items of gross margin and EBIT. (For a detailed analysis and interpretation of income statement entries, see Section 7.4.2 on ratio analysis.)

Engineering managers deploy company resources to foster the financial success of their employers. The impacts of engineering activities are registered in several line items contained in the income statement:

1. *Sales revenue*: Engineering managers increase sales revenue through well-designed products/services that satisfy the needs of customers. They introduce innovative products/services that address the needs of new customers in new markets. They refine products/services that are easy to serve and maintain, thus promoting market acceptance of the company's products/services. They also bring into being supply chains to increase the speed of product/service introduction and the extent of customization in the marketplace.
2. *Cost of goods sold*: Engineering managers cut down product/service costs by innovative design, engineering, manufacturing, and quality control.
3. *R&D*: Engineering managers advance and apply new technologies to enhance product/service features and to foster the rapid development of new global offerings.

TABLE 7.1

Example of XYZ Income Statement (Millions of Dollars)

	Year 2013	Year 2014
Sales (net) revenue	8380.30	8724.70
Cost of goods sold	6181.20	6728.80
Gross margin	2199.10	1995.90
GS&A expenses	320.7	318.8
Pensions, benefits, R&D, insurance, and others	494.6	538.7
State, local, and miscellaneous taxes	180.1	197.1
Depreciation	297.2	308.6
EBIT	906.5	632.7
Interest and other costs related to debts	82.9	114.4
Corporate tax	(32.05%) 264.00	(20.84%) 108.00
NOPAT	559.6	410.3
Common stock dividend	151.6	172.8
Retained earnings	408	237.5

TABLE 7.2

Records of Financial Entries of Advanced Technologies

No.	Items	Thousands of dollars
1	Accounts payable	3,740
2	Accounts receivable	7,550
3	Advertising expense	3,340
4	Administrative expense	5,500
5	Building (net)	36,300
6	Cash	6,320
7	Cost of goods sold	31,000
8	Depreciation expense—building	960
9	Depreciation expense—equipment	1,310
10	Equipment (net)	14,640
11	Inventory	11,000
12	Insurance expense	840
13	Interest expense	2,100
14	Land	2,100
15	Long-term loans outstanding	42,000
16	Miscellaneous expense	1,480
17	R&D	5,200
18	Salaries payable	170
19	Sales revenue	60,300
20	Supplies expense	1,820
21	Taxes expense	2,630
22	Taxes payable	610
23	Utilities expense	2,070

Example 7.1

Advanced Technologies has had quite a successful year. Its assets, liabilities, revenues, and expenses at the end of the current fiscal year are shown in Table 7.2.

Determine the net income of the company for the current year.

Answer 7.1

To determine the company's net income, we need to create the income statement for the company. As presented in Table 7.3, only selected items of Table 7.2 are to be included in the company's income statement.

7.3.2 Balance Sheet

The balance sheet is an accounting report that lists the assets owned by a company and the ways in which these assets are financed through liabilities and owners' equity. Liabilities are claims of creditors (such as banks, bondholders, and suppliers) against the company. Owners' equity represents the claims of owners (shareholders) against the company (Subramanyam 2013). The following key entries are included in a balance sheet:

1. *Assets* are items of value with a measurable worth. They are resources of economic value possessed by the company. There are three classes of assets: current, fixed, and all others.

TABLE 7.3

Income Statement of Advanced Technologies

	Thousands of dollars
Sales revenue	60,300
Cost of goods sold	31,000
Gross margin	29,300
Administrative expense	5,500
Advertising expense	3,340
Supplies expense	1,820
Utilities expense	2,070
Miscellaneous expense	1,480
Insurance expense	840
Depreciation—building	960
Depreciation—equipment	1,310
R&D	5,200
Operating income	6,780
Interest expense	2,100
Taxable income	4,680
Taxes expense	2,630
Net income	2,050

2. *Current assets* are convertible to cash within 12 months. Examples include, in descending order of liquidity, cash, marketable securities, accounts receivable, inventory, and prepaid expenses.
3. *Cash* is money on hand or in bank checks and is the most liquid form of assets.
4. *Accounts receivable* is the category of revenue recognized prior to payment collection. It is money owed to the company, usually by its customers or debtors, as the result of a credit transaction.
5. *Inventory* designates stock of goods yet to be sold that is valued at cost, including direct materials, direct labor, and manufacturing overhead. It may consist of stores, work in progress, and finished goods inventories (see Appendix 6.8.5). Inventory is included in the balance sheet as a CA.

   When finished goods are shipped and invoiced to customers in an accounting period. The CGS is then recognized in the income statement as an expense.
6. *Prepaid expenses* are paid before receiving the expected benefit (e.g., rent, journal subscription fee, or season's tickets). They are a CA.
7. *Fixed assets* are tangible assets of long, useful life (more than 12 months), such as land, buildings, machines, and equipment. Note that costs spent to improve these assets are to be added to the fixed asset value. However, repair and maintenance costs incurred in a given accounting period are expensed in the income statement.
8. *Other assets* are valuable assets that are neither current nor fixed. Examples include patents, leases, franchises, copyrights, and goodwill. Amortization accounting applies to these assets in a similar manner as depreciation is applied to fixed assets (see Appendix 6.D).

Goodwill—a company's reputation and brand-name recognition—is recognized as an asset only if it has been purchased for a measurable monetary value, such as in conjunction with a merger or acquisition transaction.

9. *Accumulated depreciation* is the sum of all annual depreciation charges taken from the date at which the fixed asset is first deployed up to the present (see Appendix 6.D).
10. *Net fixed assets* are the net value of the firm's tangible assets: original acquisition cost minus accumulated depreciation. It is possible that this net fixed asset value may deviate considerably from its market value or replacement cost in a given accounting period. The conservatism principle prescribes that the net fixed asset is carried on the balance sheet even if it is lower than its current market value—the case of underreporting the company's assets. Otherwise, an expense entry must be added to the balance sheet to correct the fixed asset value downward, should it become higher than its current market value.
11. *Liabilities* are obligations that need to be discharged by the company in the future. They represent claims of creditors (e.g., banks, bondholders, and suppliers) against the firm's assets. Sometimes, they are also called *debt*.
12. *Current liability* (CL) describes amounts due for payment within 12 months. Examples include accounts payable, short-term bank loans, interest payments, payable tax, insurance premiums, deferred income, and accrued expenses. Accounts payable is always listed first within the category of CLs, with others to follow in no specific order.
13. *Accounts payable* is an expense recognized before payment. It is an obligation to pay a creditor or supplier as a result of a credit transaction, usually within a period of one to three months.
14. *Deferred income* is income received in advance of being earned and recognized (i.e., payment received before shipment and invoicing of goods). In the balance sheet, it is included as a CL.
15. *Deferred income tax* is the amount of tax due to be paid in the future, usually within 12 months.
16. *Long-term liability* is defined as the amounts due to be paid in more than 12 months. Examples include corporate bonds, mortgage loans, long-term loans, lines of credit, long-term leases, and contracts.
17. *Bonds* are long-term debt certificates secured by the assets of the issuing entity (e.g., a company or a government). Bonds issued by a publicly held company are corporate bonds, and those issued by the U.S. federal government are treasury bonds. In case of defaults, bondholders have the legal right to seize the issuer's assets for recovery.
18. *Debentures* are unsecured bonds issued by the firm.
19. *Convertible bonds* are those debt certificates issued by a company that are allowed to be converted into common stocks according to a set of specifications (e.g., timing, conversion ratio).
20. *Owners' equity* is the shareholders' original investment plus accumulated retained earnings. It represents the residual value of the corporation owned by the shareholders after having deducted all liabilities from company assets. Sometimes it is also called *net worth*.

21. *Stock* is a certificate of ownership of a company. Preferred stocks have a fixed rate of dividend that must be paid before dividends are distributed to holders of common stocks.
22. *Capital surplus* is the premium price per share above the par value of the stock. It includes the increase in the owner's equity above and beyond the difference between assets and liabilities reported in the company's balance sheet.
23. *Retained earnings* are the accumulated earnings retained by the company, not to be paid out as dividends, for the purpose of reinvestment.
24. *Book value* is defined as the tangible assets (such as fixed assets) minus liabilities and the equity of preferred stocks. It is the share value of common stocks carried in the books.
25. *Stock price* is the market value of a firm's stock. It is influenced by the book value, earning per share, anticipated future earnings, perceived management quality, and environmental factors present in the marketplace.

    The organization of entries in a balance sheet follows this specific convention:

    a. Assets are listed before liabilities, which are then followed by owners' equity.
    b. CAs and CLs are enumerated ahead of non-CAs and CLs, respectively.
    c. Liquid assets are listed before all other assets with less liquidity.
    d. The listing of CLs follows no specific order, except that accounts payable must always be listed first in this category.

The contributions of engineering managers affect only one line item in the balance sheet, namely, inventories. Inventories may be reduced by applying superior production technologies, product design, and best practices of supply chain management. Table 7.4 shows a sample balance sheet of XYZ Company.

Example 7.2

Using the data given in Table 7.2, construct the balance sheet of Advanced Technologies and determine the owners' equities at the end of the current fiscal year.

Answer 7.2

The owners' equities are $29,120 at year end (see Table 7.5).

7.3.3 Funds Flow Statement

The funds flow statement compares the firm's activities in two consecutive accounting periods and elucidates the major sources and uses of funds of the firm. It is sometimes also called the *statement of changes in financial position* or the *statement of sources and uses of funds*.

The principle behind the funds flow analysis is rather simple. An increase in assets signifies a use of funds, such as buying a plant facility by paying cash or using credit. A decrease in assets indicates a source of funds, such as selling used equipment to receive cash. An increase in liabilities produces a source of funds, such as borrowing money from a bank so that more cash is available for other purposes. A decrease of liabilities yields a use of funds, such as paying down a bank loan by using money from

TABLE 7.4

Example of XYZ Balance Sheet (Millions of Dollars)

	Year 2013	Year 2014
Assets		
Cash	231	245.7
Marketable securities	450.8	314.9
Accounts receivable	807.1	843.5
Inventories	1,170.70	1,387.10
Total CAs	2,659.60	2,791.20
Fixed assets	11,070.40	11,897.70
Accumulated depreciation	6,410.70	6,618.50
Net fixed assets	4,659.70	5,279.20
Long-term receivables and other investments	574.8	735.2
Prepaid expenses	260.9	362.3
Total long-term assets	5,495.40	6,376.70
Total Assets	**8,155.00**	**9,167.90**
Liabilities		
Accounts payable	571.2	622.8
Notes payable	65.3	144.5
Accrued taxes	346.3	275
Payroll and benefits payable	433.7	544.3
Long-term debt due within a year	30.4	50.8
Total CLs	1,446.90	1,637.40
Long-term debt	1,542.50	1,959.90
Deferred tax on income	288.4	405.3
Deferred credits	27	36.3
Total long-term liabilities	1,857.90	2,401.50
Total liabilities	**3,304.80**	**4,038.90**
Common stock ($1.00 par value)	81.4	82.2
Capital surplus	1,549.10	1,589.60
Accumulated retained earnings	3,219.70	3,457.20
Total owner's equity	**4,850.20**	**5,129.00**
Total liabilities and owners' equity	**8,155.00**	**9,167.90**

the company's cash reservoir. Table 7.6 presents an example of the funds flow statement of XYZ Company.

The funds flow statement shown in Table 7.6 is generated by using the data in Tables 7.1 and 7.4:

1. *Increase in long-term debt*
   a. Increase in long-term debt (1959.9 − 1542.5) = 417.4
   b. Increase of long-term debt due within one year (50.8 − 30.4) = 20.4
   c. Total (417.4 + 20.4) = 437.8
2. *Increase in plants and equipment*
   a. Increase in fixed assets (11,897.7 − 11,070.4) = 827.3
   b. Increase in long-term receivable and other investments (735.2 − 574.8) = 160.4

TABLE 7.5

Balance Sheet of Advanced Technologies

	Thousands of Dollars
Cash	6,320
Accounts receivable	7,550
Inventory	11,000
Total CAs	24,870
Land	2,100
Equipment (net) ($14,640–1,310)	13,330
Building (net) ($36,300–960)	35,340
Total assets	75,640
Accounts payable	3,740
Taxes payable	610
Salaries payable	170
Long-term loans outstanding	42,000
Total liabilities	46,520
Owners' equities	29,120
Total liabilities and owners' equities	75,640

c. As details are missing, we introduce the following reasonable assumption:
   i. Long-term receivables = 59.6
   ii. Increase in other investment (160.4 − 59.6) = 100.8

d. Total increase in fixed asset investment (827.3 + 100.8) = 928.1

3. *Increase in common stock and capital*
   a. Increase in common stocks (82.2 − 81.4) = 0.8
   b. Increase in capital surplus (1589.6 – 1549.1) = 40.5
   c. Total (0.8 + 40.5) = 41.3

Most other line items in this funds flow statement are directly verifiable using data in Table 7.4. By reviewing the percentages contained in the rightmost column of Table 7.6, managers will have a clear picture regarding how funds are created (e.g., 25.5% from raising debt and 24.86% from net income earned) and how they have been spent (e.g., 56.23% for fixed assets and another 13.11% for building up inventories). These numbers suggest that XYZ Company is borrowing heavily to build plants and inventories to pursue a business expansion strategy.

7.3.4 Linkage between Statements

The three financial statements described in Sections 7.3.1 through 7.3.3 are linked to one another. The net profit in the income statement is linked with the retained earnings in the balance sheet. The inventory account in the balance sheet is linked with the sales revenue in the income statement. The accumulated depreciation in the balance sheet is linked with the annual depreciation charge included in the income statement. Because the depreciation charge taken in a given period affects the net profit of the company during the same period, it is thus indirectly linked to the retained earning account in the balance sheet as well.

TABLE 7.6

Example of XYZ Funds Flow Statement (Millions of Dollars)

	2013–2014	Percentage
Sources		
Increase in long-term debt	437.8	26.50
Net income	410.3	24.86
Depreciation	308.6	18.7
Decrease in marketable securities	135.9	8.23
Increase in deferred taxes on income	116.9	7.08
Increase in payroll and benefits payable	110.6	6.70
Increase in notes payable	79.2	5.00
Increase in accounts payable	51.6	3.13
Total Sources of Funds	**1651.30**	**100.00**
Uses		
Increase in fixed assets and other investments	928.1	56.23
Increase in inventories	216.4	13.11
Dividend paid	172.8	10.47
Increase in prepaid expenses	101.4	6.14
Increase in long-term receivables	59.6	3.61
Decrease in accrued taxes	71.3	4.32
Increase in capital surplus	41.3	2.45
Increase in accounts receivable	36.4	2.21
Increase in cash	14.7	0.90
Increase in deferred credits	9.3	0.60
Total Uses of Funds	**1651.30**	**100.00**

The linkage between the funds flow statement and the other two financial statements is self-evident, as all data in the funds flow statement are derived from changes in various line items in the other two statements.

7.3.5 Recognition of Key Accounting Entries

This section offers additional notes on the recognition of several key accounting entries—assets, liabilities, revenues, and expenses—according to GAAP practiced in many countries. Some countries may have slightly different rules governing the report of these items.

1. *Assets* are the resources under company control. They have economic value and can be used to produce future benefits. Assets recognition is based on two principles: historical cost and conservatism (Schoenebeck and Holtzman 2012). All assets are reported by using historical cost: that is, the initial capital investment value at some time in the past. The book value of a given asset is defined as its initial acquisition cost minus the accumulated depreciation. Should the asset's current market value drop below its book value, the shortfall must be reported as an expense. If its market value exceeds its book value, however, the surplus is not reported in the company's balance sheet. This is to ensure that the asset value included in the balance sheet always denotes its lower bound. Thus, the balance sheet may understate the true value of the company's assets.

Asset reporting must address two specific issues: asset ownership and the certainty of its future economic benefits. If neither the ownership nor the future benefits are clearly established, an asset cannot be recognized. For example, companies routinely invest in employee training in the hope that doing so will lead to increased productivity at a future point in time. Since the completed training is really owned by the individual employees involved, and employees may leave at any time they wish, companies do not have real ownership of the training results. Thus, employee training is regarded as an expense and not an asset. When companies acquire plant facilities to make products for sales in the marketplace, the future benefits are more or less certain. Plant facilities are thus reported as assets. When companies apply resources to expand R&D and advertising, the future benefits of these investments are neither certain nor measurable. R&D and advertising are thus recognized as expenses and not assets.

GAAP accounting rules in the United States (Flood 2014) contain one exception: generally speaking, software development costs are to be reported as expenses as they are incurred. However, once the company management becomes confident that the software development efforts can be completed and the resulting software product will be used as intended, all development costs incurred from that point are to be reported as assets.

There are several ambiguities in the accounting rules practiced in the United States:

a. *Buying versus developing*: If Company A acquires Company B by paying a purchase price that exceeds Company B's net asset value, this excess value is called goodwill. Goodwill includes the intangible assets of Company B, such as its brand name, trademarks, patents, R&D portfolio, and employee skills. After the merger, the surviving company has part of its R&D (from the original Company A) recognized as expenses and part of the R&D (acquired from Company B) as assets.
b. *Valuing intangible assets*: "If you can't kick a resource, it really isn't an asset." This saying is typically the justification used by companies to rapidly write off intangible assets from their balance sheets. Often, goodwill is significantly overvalued in a merger or acquisition transaction due to potential conflicts of interests among the parties involved. Writing off intangible assets distorts the true value of the assets reported in the company's balance sheet.
c. *Market value*: U.S. accounting rules prescribe that marketable securities (e.g., bonds) are to be reported at their fair market values only if they are not to be held to maturity. Thus, at any given time, the real asset value of a company is distorted by not reporting the current true market values of these assets in balance sheets.

2. *Liabilities* are obligations to be satisfied by transferring assets or providing services to another entity (e.g., a bank, a supplier, or a customer).

A liability is recorded when an obligation has been incurred and the amount and timing of this obligation can be measured with a reasonable amount of certainty. For multiple-year commitments, the recordable obligation is the present value of expected future commitments, wherein the discount rate is the prevailing rate when the obligation was first established.

3. *Revenues* recognition must satisfy two conditions: revenue is earned when (1) all or substantially all of the goods or services are delivered to the customers and (2) it is likely that the collection of cash or receivables will be successful. Generally speaking, the timing of product or service delivery may not be the same as that for payment collection.

   For magazine subscriptions, insurance policies, and service contracts, customers usually pay in advance. In these cases, payments received ahead of the service delivery dates are kept in a "deferred revenue" account. Only after the pertinent service is delivered will the applicable payments be credited to the revenue T-account during the accounting period. T-accounts will be discussed in Appendix 7.A. For products sold on credit, companies recognize the revenue as soon as the products are shipped out, and invoices are issued to customers ahead of the payment collection.

   In the case of construction projects, which usually stretch out over many accounting periods, revenues are recognized in T-accounts by using the *percentage completion* method and are recognized in proportion to the expenses incurred in the project.

   For products sold with money-back guarantees, companies recognize revenue at the time the product is delivered. At the end of an accounting period, management makes an estimate of the cost of returns (a liability) to adjust the revenue figure.

4. *Expenses* are economic resources that either have been consumed or have declined in value during an accounting period. Expenses are typically recorded in the form of a reduction of asset value (e.g., cash) or by a creation of liability (e.g., accounts payable).

   There are three types of expenses: (1) consumed resources having a cause-and-effect relationship with revenue generated during the same accounting period (e.g., CGS); (2) other resources consumed during the same accounting period, but having no cause-and-effect relationship with revenue (such as R&D expenses, advertising expenses, depreciation charges, local taxes, pension expenses, and other general administrative expenses); (3) reduction of expected benefits of company assets generated by past investments (e.g., the write-down of production facilities and equipment that is no longer of value due to the noncompetitiveness of products or technological obsolescence).

Example 7.3

Superior Technologies sells a product at the unit price of $100. The unit cost of the product is $60. Annual sales have averaged one million units, and its annual selling expense has been $7 million. Market research has determined that if the selling price of the company product is decreased to $90, there will be a 35% increase in the number of units sold. The engineering department estimates that if the production volume is increased by 35%, it will reduce the unit product cost by 10% due to the scale of economies. To market the 35% increase in sales volume, the company's selling expense will need to increase by about 50%.

The company's current warehouse facilities are sufficiently large to accommodate the possible increase of 35% in sales volume without requiring new investment. Furthermore, regardless of the product price, the company is obliged to pay an annual loan interest of $2 million. Its corporate tax rate is 45%. It maintains an R&D department,

TABLE 7.7

Superior Technologies Operational Analyses

	Current Operation ($)	Operation with Increased Unit Sales ($)
Units of product sold	1,000,000	1,350,000
Product price	100	90
Unit product cost	60	54
Sales revenue	100,000,000	121,500,000
Cost of goods sold	60,000,000	72,900,000
Gross margin	40,000,000	48,600,000
Selling expense	7,000,000	10,500,000
Administrative expense	15,000,000	15,000,000
R&D	5,000,000	5,000,000
Depreciation	2,000,000	2,000,000
EBIT	11,000,000	16,100,000
Interest	2,000,000	2,000,000
Taxable income	9,000,000	14,100,000
Tax (45%)	4,050,000	6,345,000
Net income	4,950,000	7,755,000

whose operation is independent of the sales units, at an annual cost of $5 million. Its administrative expense is $15 million, which is also independent of the sales activities. In addition, the company incurs a pretax depreciation charge of $2 million.

Determine whether the reduction of product price would increase or decrease the net income of the company and by how much.

Answer 7.3

The reduction of product price will cause the company's net income to increase to $7.755 million from $4.95 million (see details in Table 7.7).

7.3.6 Caution in Reading Financial Statements

In the United States, companies follow the rules set by the Financial Accounting Board (FASB), an industrial panel, when preparing financial statements. Even so, these financial statements are not always created equal; they need to be studied carefully because of the following built-in variations.

1. *Depreciation accounting base*: Some companies may use the straight-line method, whereas others may choose to use the double-declining method, as both are allowable (Appendix 6.D).
2. *Inventory accounting method*: Some companies use the first in and first out (FIFO) method, whereas others may choose to use last in and first out (LIFO). In time periods with high price volatility, the inventory value will be affected by the method chosen (Appendix 6.E).
3. *Cost of capital*: Dependent on the debt-to-equity ratio and the costs of raising equity and debt, the weighted average of cost of capital will be different from one company to another.
4. *Difference between book and market values*: The book value of a company's fixed assets is calculated by subtracting the accumulated depreciation from its initial

acquisition prices. These values may be quite different from the assets' current market values, which, in turn, are dependent on supply and demand in the marketplace and the overall economy.

5. *Long-term liabilities reportable*: The current FASB rules do not require companies to report long-term liabilities associated with pension, health care and other such obligations in balance sheets, although these liabilities are typically disclosed in footnotes and other such obscure places within the companies' annual reports. Some companies with a heavily unionized workforce could therefore create the illusion of having a higher net worth than otherwise for unsophisticated investors. It is important to keep such long-term liabilities in mind when reading financial statements.

7.4 Fundamentals of Financial Analysis

The purpose of conducting financial analyses is to assess the effectiveness of the company's management in achieving the objectives set forth by the company's board of directors with respect to a number of critically important business factors (Revsine et al. 2014). Such factors include liquidity, activities, profitability, capitalization, and stock value. Typically, the corporate objectives of industrial companies are growth, profitability, and return on investment (ROI). Many of these financial terms will be defined and explained in this section.

The *growth* objective suggests that companies keep product prices low, increase marketing expenses, run plants at full capacity, take loans to keep inventory high, strive for a larger market share, and attain a more dominant market position. The *profitability* objective dictates that companies set prices high to maximize profits, run plants at a capacity that minimizes costs (production and maintenance), and use debt when called for. The *ROI* objective is to operate the company by maximizing its financial return with respect to the firm's investment (e.g., the "milk-the-cash-cow" strategy. See Section 9.5.4).

Financial analyses focus on studying the period-to-period changes in key financial data and on comparing performance ratios with the industrial standards.

7.4.1 Performance Ratios

In this section, we apply a specific system of calculating performance ratios by grouping together the ratios for liquidity, activities, profitability, capitalization, and stock value (Bragg 2012). In order to understand the system, we will need to introduce the following terms:

1. *Liquidity*: is the firm's capability to satisfy its CLs, such as buying materials, paying wages and salaries, paying interests on long-term debt, and other necessary expenditures. Without liquidity, there can be no activity.

   Working capital is defined as CAs minus CLs. The changes in working capital over several periods provide an indication of the company's reserve strength to weather financial adversities.

   Current ratio is the ratio of CAs to CLs. CAs are frequently considered the major reservoir of funds for meeting current obligations. CLs (CL) are short-term obligations to be discharged within the next three months, such as salaries, accounts payable, taxes, interest payments, utilities, etc. This ratio provides an indication of the company's ability to finance its short-term operations over the next 12 months. A current ratio above 1.0 indicates a margin of safety that allows for a possible shrinkage of value in CAs such as inventories and accounts receivables. However, having a current ratio in excess of 2.0 or 3.0 may indicate a poor cash management practice.

Quick ratio is the ratio of quick asset to CLs. *Quick asset* is defined as cash plus marketable securities and accounts receivable. This ratio is more restrictive than the current ratio in that it excludes the value of inventory whose liquid value may not be certain. Thus, the quick ratio indicates the company's ability to meet its financial obligations over the next 12 months without the use of inventory that may take time to unload. It is sometimes also called the *acid test* or *liquidity ratio*.

2. *Activity*: The changes in sales and inventory. Successful activity leads to profitability.

   Collection period ratio is the accounts receivable divided by average daily sales as measured in days. The average daily sales is the total annual sales divided by 360 days. This ratio measures the managerial effectiveness of the credit department in collecting receivables and the quality of accounts receivable.

   Inventory turnover ratio is the CGS divided by the average inventory. It expresses the number of times during a year that the average inventory is recouped or turned over through the company's sales activities. The higher the turnover, the more efficient the company's inventory management performance will be. A good inventory management system will create no shortage of inventory, as such a shortage will result in a loss of sales and failure to satisfy customers' needs.

   Asset turnover ratio of net sales to total assets indicates the ability of the company's management to use total assets to generate sales.

   Working capital turnover ratio is net sales to working capital. Working capital is defined as average CAs minus average CLs. It indicates the company's ability to efficiently use working capital to generate sales.

   Sales to employee ratio is the company's net sales revenue divided by its average number of employees working during an accounting period. It measures the company's ability to effectually use human resources.

3. *Profitability*: To be profitable is the objective of most companies. Without liquidity and activity, there can be no profitability. If the company is profitable, it can readily secure the required liquidity to keep its operations continuing.

   Gross margin percentage is defined as gross margin divided by sales revenue. It measures the company's profitability on the basis of sales. Gross margin is defined as sales minus CGS.

   Net income-to-sales ratio indicates the company's overall operational efficiency (e.g., procurement, cost control, CAs deployment, and use of financial leverage) in creating profitability based on sales. This ratio is also known as *return on sales* (ROS).

   Net income to owners' equity ratio measures profitability from the shareholders' viewpoint. It is also known as *return on equity* (ROE). Owners' equity is defined as total assets minus total liability of the company, representing the net worth, which belongs to the investors. This very common measure indicates the earning power of the ownership investment in the company.

Net income to total asset ratio is net income divided by total assets. It measures the management's ability to effectively apply company assets in generating profits. It is known as *return on assets* (ROA).

4. *Capitalization*: The sum of the company's long-term liabilities and owners' equity is defined as the total capital deployed by company management to pursue business opportunities. Several ratios are in use to check this capital deployment effectiveness.

   Interest coverage ratio (EBIT divided by the interest expense) calculates the number of times the company's EBIT covers the required interest payment for the long-term debt—an indication of the company's ability to remain solvent in the near future. EBIT is defined as earnings before interests and taxes. EBIAT is defined as earnings before interests and after tax.

   Long-term debt to capitalization ratio is the ratio of long-term debt to the sum of long-term liabilities plus owner's equity—the total permanent investment in a company, indicating the percentage of long-term debt in the company's capital structure, excluding CLs. It is a measure of the company's financial leverage. Keeping this ratio small (hence, large owners' equity percentage) may not always be the smart choice, as the company will forgo the use of low-cost debt with tax-deductible interest payments to enhance profitability.

   Return on invested capital is the ratio of net income divided by capital. The capital of a company is the sum of its long-term liabilities plus owners' equity.

   Debt-to-equity ratio is the ratio of total liability to owners' equity. It also measures the company's financial independence and the relative stake of shareholders (insiders) and bondholders (outsiders). A low ratio indicates that the company is financially secure as far as the owners are concerned. A high ratio indicates that the firm is highly leveraged and may thus have difficulty borrowing money in the future.

5. *Stock value*: This is the market price or value of the company's stock as defined by the financial markets. The company's management is obliged to pursue proper business strategies in order to steadily raise its stock value.

   Earnings per share is the ratio of net income minus preferred stock dividends divided by the number of common stocks outstanding.

   Price to earning ratio is the ratio of the market price of common share to earning per share.

   Market to book ratio is the ratio of market price of stock to the company's book value per share. More precisely, the total book value of a company is defined as the total assets minus intangible assets, minus total liability, and minus the equity of preferred stocks. In computing the total assets of the company, the value of fixed assets is determined by the difference of their initial investment minus accumulated depreciation, irrespective of the assets' current market value. The book value per share is then the total book value divided by the number of outstanding common shares.

   Dividend payout ratio is the ratio of dividends per share divided by earnings per share. It indicates the percentage of annual earnings paid out as dividends to shareholders. The portion that is not paid out goes into the retained earnings account on the balance sheet. The retained earnings are a part of owner's equity.

7.4.2 Ratio Analysis

Ratios are useful tools of financial analysis (Marck 2014; Healy & Cohen 2000; Tracy 2012). Sometimes, ratios of significant financial data are more meaningful than the raw data themselves. They also provide an instant picture of the financial condition, operation, and profitability of a company, provided that the trends and deviations reflected by the ratios are interpreted properly.

Ratio analyses are subject to two constraints: past performance and various accounting methods. *Past performance* is not a sure basis for projecting the company's condition in the future. *Various accounting methods* employed by different companies may result in different financial figures (e.g., inventory accounting and depreciation), rendering a comparison that is less meaningful between companies in the same industry. Typically, accountants try to reconcile financial statements before conducting comparative analyses. Examples of adjustments that are frequently made include:

1. Adjusting LIFO inventories to a FIFO basis (Appendix 6.E).
2. Changing the write-off periods of intangible assets, such as goodwill, patents, and trademarks (Appendix 6.D).
3. Adding potential contingency liabilities if lawsuits are pending (Section 6.4.5).
4. Reevaluating assets to reflect current market values (Section 7.3.2, entry (4)).
5. Changing debt obligations to reflect current market interest rates.
6. Restating reserves or charges for bad debts, warranties, and product returns.
7. Reclassifying operating leases as capital leases.

When performing ratio analyses, it is advisable to follow this set of generally recommended guidelines:

1. Focus on a limited number of significant ratios.
2. Collect data over a number of past periods to identify the prevalent trends.
3. Present results in graphic or tabular form according to standards (e.g., industrial averages).
4. Concentrate on all major variations from the standards.
5. Investigate the causes of these variations by cross-checking with other ratios and raw financial data.

In the financial literature, many of the ratios defined in Section 7.4.1 are systematically collected and published for key companies in various industries by investment services companies. Sources of information on ratios and other financial measures are typically reported regularly and made available for use by the public in publications such as Value Line Investment Survey, Standard & Poor's Industrial Survey, and Moody's Investors Services. STEM professionals should develop the habit of reading and considering such reports.

Other commercial sources are accessible through the Internet. For the 500 stocks comprising Standard & Poor's index, five specific ratios—current ratio, long-term debt to capital, net income to sales, return on assets, and return on equity—are published in

TABLE 7.8

XYZ Company Income Statement

	2012	2013
Sales	330,000	395,000
Cost of sales	265,000	280,000
Gross profit	65,000	115,000
Selling and administrative[a]	95,000	88,000
Other expenses	4,000	3,500
Interest	2,000	3,000
Profit before taxes	(36,000)	20,500
Federal income tax	0	10,000
Net income (loss)[b]	(36,000)	10,500

[a] Includes depreciation of $15,500 in 2012 and $15,000 in 2013.

[b] No dividends paid in 2012.

TABLE 7.9

XYZ Company Balance Sheet

	2012	2013
Assets		
Cash	18,500	17,000
Marketable securities	0	5,000
Accounts receivable	39,500	28,500
Inventories	98,000	113,000
Total CAs	156,000	163,500
Plant and equipment (net)	275,000	290,000
Other assets	3,000	8,000
Total assets	434,000	461,500
Liabilities		
Accounts payable	34,500	18,000
Notes payable	20,000	25,000
Accrued expenses	18,500	11,500
Total CLs	73,000	54,500
Mortgage payable	20,000	30,000
Common stock	200,000	200,000
Earned surplus	141,000	177,000
Total liabilities and equities	434,000	461,500

a widely available special guide for consecutive 10-year periods (Standard and Poor's 2013).

Example 7.4

For the years 2012–2013, the financial statements of XYZ Company are given in Tables 7.8 and 7.9. Define the performance ratios of the company.

Answer 7.4

The 2012 performance ratios of XYZ Corporation are

1. *Liquidity*
   a. Current ratio = CA/CL = 3.1
      From the creditor's standpoint, this ratio should be as high as possible. On the other hand, prudent management will want to avoid the excessive buildup of idling cash or inventories (or both).
   b. Quick ratio = Quick assets/CL = 0.931
      A result far below 1:1 can be a warning sign.
   c. Interest coverage ratio = 7.833
      The EBIT of the firm could pay 7.833 times the interest and other costs associated with the long-term debts. This ratio is good.
2. *Debt versus equity*
   a. Long-term debt to capitalization ratio = 4.44%
      This debt level is prudent for firms in this industry.
   b. Total debt to owners' equity = 22.4%
      Total debt = CL + long-term debt.
      OE = Common stock plus capital surplus plus accumulated retained earnings.
   c. Total debt to total asset ratio = 18.3%
3. *Activity*
   a. Sales to asset ratio = 0.86
   b. Ending inventory to sales ratio = 28.6%
   c. CGS/average inventory = 2.65 times
      Average inventory = the average of ending inventory of two consecutive years (e.g., 2012 and 2013)
4. *Profitability*
   a. Net income to owner's equity ratio = 2.8%
   b. Net income-to-sales ratio = 2.66%
   c. Gross margin to sales ratio = 29.1%
   d. EBIT to total asset ratio = 5.1%
   e. Net income to total asset ratio = 2.3%
   f. EBIT to sales ratio = 5.9%

7.4.3 Economic Value Added

Developed by Stern Stewart & Company in 1989, economic value added (EVA) is an improved valuation method for asset-intensive companies or projects. EVA is defined as the after-tax-adjusted net operating income of a company minus the total cost of capital spent during the same accounting period. It is also equal to the return on capital minus the cost of capital, or the economic value above and beyond the cost of capital (Stewart 2013; Ismail 2011). Sometimes EVA is also called *economic profit*. In equation form, it is defined as

$$\text{EVA} = \text{NOPAT} - \text{WACC}\left(\text{Capital Deployed}\right) \tag{7.1}$$

where:

NOPAT	= net operating profit after tax (net income)
Capital Deployed	= total assets − CLs
WACC	= weighted average of cost of capital (equity and debt) employed in producing the earnings (Section 7.6.3)

If EVA is positive, the company is said to have added positive shareholder value. If EVA is negative, the company is said to have diminished shareholder value.

EVA may also be applied to a single project by calculating the after-tax cash flows generated by the project minus the cost of capital spent for the project. For example, the NPV equation can be modified as follows:

$$\text{NPV} = -P + \left[\sum_{t=1}^{N} \frac{C_t - P \times \text{WACC}}{(1+\text{WACC})^t}\right] + \frac{\text{SV}}{(1+\text{WACC})^N} \tag{7.2}$$

where:

t	= 1 to N
NPV	= net present value (dollars)
P	= investment capital for the project (dollars)
C_t	= net after-tax cash inflow (dollars) to be produced by the project in period t
$P \times$ WACC	= cost of capital (dollars) spent during period t
WACC	= weighted average cost of capital in effect (fraction)
SV	= salvage value of the project at the end of period N
N	= number of period

The major advantage of EVA over ROC is that it may encourage managers to undertake desirable investments and activities that will increase the value of the firm. The next example shows the difference between these two methods.

ABC Company has established that its WACC is 10% and its ROC standard for investment purposes is 14%. The management is considering a new capital investment that is expected to earn a return of 12%. This new investment is attractive according to the EVA criterion, as 12% is larger than 10%. However, this new investment is a poor choice if evaluated with the ROC criterion, because 12% is less than 14%. Thus, by using the ROC criterion to evaluate investments, the company may lose the opportunity to create shareholder value.

Engineering managers should learn to apply EVA as a supplementary measure, besides net income after tax, to assess business performance.

7.5 Balanced Scorecard

Financial ratios are developed by accountants, who naturally emphasize the companies' financial performance of direct interest to shareholders. Nonfinancial ratios are limited in number and restricted in scope. Examples include accounts receivable, collection, inventory, use of fixed assets, and working capital.

All financial ratios are determined on the basis of past performance data; they are "trailing" indicators, and as such, they cannot foretell the future performance of a company. Because financial ratios are oriented toward the short term, usually from one quarter to another, company management is inadvertently forced to overemphasize short-term financial results, often to the extent of neglecting the company's long-term growth. The narrow focus of these financial ratios makes them no longer completely relevant to today's business environment, in which customer satisfaction, employee innovation, business joint ventures, global orientation, and continuous betterment of business processes are key elements of company competitiveness in the marketplace (Niven 2014).

These basic deficiencies in financial ratios are well recognized in industry. Attempts have been made in the past to modify these ratios as corporate measurement metrics. Kaplan (1996) suggests that corporate measurement metrics are to be defined to cover four areas:

- *Financial*: Shareholder value
- *Customers*: Time, quality, performance and service, and cost
- *Internal business processes*: Core competencies and responsiveness to customer needs
- *Innovation and corporate learning*: Value added to the customer, new products, and continuous refinement

The significance of the balanced scorecard lies in its balanced focus on both short-term actions as well as long-term corporate growth. Cutting R&D and marketing expenses is a known way for many companies to emphasize short-term performance at the expense of long-term health. Spending adequate company effort on innovation to bring out new products is promoting long-term health. Ideally, metrics should be set up to track outcomes in both short-term performance and long-term health, which is related to company growth prospects, capabilities, relationships, and assets, to enable future cash flows. Companies must create metrics to track outcome in both performance and health. Specifically, Kaplan (1996) advocates the use of a total of 15–20 metrics to cover these four areas to guide the company as it moves forward.

As an illustrative example, the balanced scorecard metrics for a manufacturing company may contain the following:

1. *Financial*: Cash flow, quarterly sales growth and operational income, increased market shares, and return on equity
2. *Customer*: Percentage of sales from new products, percentage of sales from proprietary products, on-time delivery as defined by customers, share of key account's purchase, ranking by key accounts, and number of collaborative engineering efforts with customers
3. *Internal business process*: Manufacturing capabilities versus competition, manufacturing excellence (cycle time, unit cost, and yield), design engineering efficiency, and new product introduction schedule versus plan
4. *Innovation and learning*: Time to develop next-generation technology, speed to learn new manufacturing processes, percentage of products that equal 80% of sales, and new product introduction versus competition

In general, balanced scorecard metrics for a given company must be developed according to its corporate strategy and vision, using a top-down approach. Doing so will ensure that performance metrics at lower management levels are properly aligned with the overall corporate goals. A unique strength of balanced scorecard metrics is that they link the company's long-term strategy with its short-term actions. These metrics contain forward-looking elements at the same time as they balance the internal and external measures. The creation of such metrics provides clarification, consensus, and focus on the desired corporate outcome.

In the literature, United Parcel Service is known to have achieved an increase of 30%–40% in profitability with balanced scorecard metrics. Mobil Oil's North American

Marketing and Refining Division raised its standing from last to first in its industry after having implemented a balanced scorecard. Person (2013) recommends that managers, when implementing a balanced scorecard, take personal ownership, nurture a core group of champions, educate team members, keep the program simple, integrate the scorecard into their own leadership systems, orchestrate the dynamics of scorecard meetings, communicate the scorecard widely, resist the urge for perfection, be ruthless about implementation, and look beyond the numbers to achieve cultural transformation of the company.

A widespread use of broad-based metrics, such as those suggested by the balanced scorecard, is likely to shift the attention of corporate management from a focus primarily on financial performance to other areas of equal importance, such as customers, internal business processes, and innovation and learning. Contributions made by engineering managers in these nonfinancial areas will likely become readily and more favorably recognized in the future.

7.6 Capital Formation

Capital formation refers to activities undertaken by a company to raise capital for short-term and long-term investment purposes (Piketty 2014; Sherman 2012).

In general, the net income earned by most companies, plus their internal resources of retained earnings, are not sufficient to finance all investments needed to achieve both their short-term and long-term corporate objectives. Even if these internal resources are sufficient, some companies still engage in external financing due to valid reasons related to tax and strategic management flexibility. Many companies routinely pursue some external financing resources, such as equity or debt financing, or both.

7.6.1 Equity Financing

Equity financing is the raising of capital by issuing company stocks. Stocks are certificates of company ownership, which typically carry a par value of $1. The price of the same stock in the market (e.g., the New York Stock Exchange) may fluctuate in time as a consequence of national economic conditions, industrial trends, political stability, and other factors unrelated to company performance. Shareholders are those who own stocks. They have the residual claims to what is left of the firm's assets after the firm has satisfied other high-priority claimants (e.g., bondholders, bankruptcy lawyers, and unpaid employees). Basically, there are two kinds of stocks: *common stocks* and *preferred stocks* (whose dividends have a priority over those of common stocks).

Companies may issue new stocks to raise capital. The process requires the approval of the company's board of directors (which mirrors the interests of all shareholders), because such a move may result in the dilution of company ownership. In addition, a public stock offering needs to be registered with the federal government (e.g., the U.S. Securities and Exchange Commission) and organized by an underwriting firm. The underwriting firm helps set the offering price, prepares the proper advertisements, and assists in placing all unsold issues to ensure a successful completion of the equity financing process. Companies issuing new stocks will incur an issuing expense.

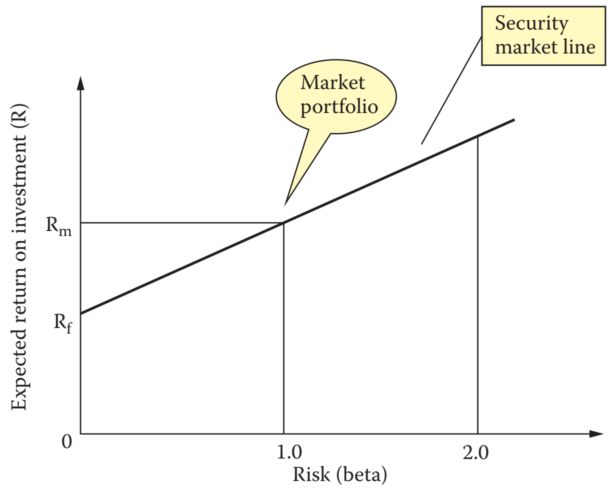


FIGURE 7.1
Market risk premium.

The capital received by issuing stocks has a cost made up of the following components: the cost of equity capital, which includes the stock issuing fees; the dividends to be paid in future years; and the capital gains through stock price appreciation expected by investors in the future. Typically, this cost of equity is set to equal the return of an equity calculated by using the well-known capital asset pricing model (CAPM) (Hart 2014).

The CAPM defines the return of an equity as (see Figure 7.1)

$$r = R_f + \beta\left(R_m - R_f\right) \tag{7.3}$$

where:

R_f	= risk-free rate (e.g., 6.0% of 10-year U.S. Treasury bills)
R_m	= expected return of a market portfolio, a group of stocks representing the behavior of the entire market (e.g., S&P 500 Index). R_m depends on conditions not related to the individual stocks. The typical value for R_m is in the range of 15%, based on long-term U.S. market statistics
β (Beta)	= relative volatility of a stock in comparison to that of a market portfolio, which by definition has a Beta of 1.0. The Standard & Poor's 500 stocks serve as a proxy for the overall market. If the Beta of a stock is 1.5, then its price will change by 1.5% for every 1.0% price change of the market portfolio in the same direction. An issue with a Beta of 0.5 tends to move 50% less. A stock with a negative Beta value tends to move in a direction opposite to that of the overall market. Stocks with large Beta values are more volatile and hence more risky. Beta values are published in the financial literature for most stocks that are publicly held.
$R_m - R_f$	= market risk premium.

Since the value of Beta is based on historical data, numerous financial analysts view it as a major deficiency of the CAPM model. Another deficiency is its lack of timing constraints.

The same cost is assumed to be valid for capital projects of a 2- or 10-year duration. In practice, when evaluating a specific capital investment project, some companies adjust the value of Beta manually in order to arrive at a pertinent cost of equity capital.

7.6.2 Debt Financing

Debt is the liabilities incurred by the company to make contractual payments (e.g., interest payments) under specified terms. Debt represents a fixed prior claim against the company's assets and poses a financial risk to the company. Companies create creditors by issuing industrial bonds or taking loans from financial institutions. Debts are usually secured by a certain part of the company's assets. Creditors have the legal power to enforce payments and thus potentially drive companies into bankruptcy. When a company declares bankruptcy, it must satisfy the claims of creditors in a specific order: (a) secured debts (bonds or loans), (b) lawyers' fees, (c) unpaid wages, and (d) stockholders. Note that bankruptcy lawyers have a payment priority ahead of the hardworking employees and risk-averse shareholders (Chaplinsky 2010).

Companies seeking debt financing through the issuance of bonds also need to engage an underwriting firm and follow a set of prescribed steps. There are several types of bonds: (a) corporate bonds, (b) mortgage bonds, (c) convertible bonds (convertible to stocks at a fixed price by a given date), and (d) debentures (unsecured bonds). The length of debts may be short term (less than one year's duration), intermediate (one to seven years), or long term (more than seven years). There is also an underwriting fee associated with this type of public offering.

Companies seeking debt financing through loans will typically negotiate for terms and conditions directly with the lending financial institutions involved. The interest rate charged is usually the prevalent prime rate plus a surcharge rate. The prime rate is published by the Federal Reserve Board on a regular basis as a means to control the liquidity of the financial markets. The surcharge rate varies with the company's credit rating, which in turn depends on the company's past financial performance and future business prospects. The higher the company's credit rating, the lower is this surcharge rate. Hence, better-performing companies may borrow money at cheaper rates. This reflects the lower risks involved for the lenders.

The cost of debt capital includes the underwriting fee, bond rate, or interest rate to be paid in future periods, the opportunity cost associated with the diminished company growth opportunity, and other costs.

The opportunity cost related to reduced growth opportunity results from the fact that highly leveraged companies can no longer be as aggressive in pursuing new growth business opportunities as they might be in the case of no or minimum leverage. The obligatory interest burdens tend to temper the company's otherwise bold investment strategies. These burdens also constrain the company's investment flexibility and thus cause the company to lose the potential benefits that it could otherwise have realized from such new opportunities. Examples of such new opportunities include the development of new products, engagement in leading-edge R&D, entrance into new global markets, and creation of new and innovative supply chain partnerships.

The other costs could result from one or more of the following: (1) suboptimal operational policies that aim at the lower end of a range of sales forecasts; (2) vulnerability of the company to attacks by competitors; (3) the company's inability to access additional debt capital, if needed; and (4) the cost of bankruptcy.

TABLE 7.10

Balance Sheet of Innovative Products (2014)

	Year 2014 ($)
Cash	40,000
Accounts receivable	160,000
Notes receivable	70,000
Inventories	260,000
Prepaid items	16,000
Total CAs	546,000
Land	25,000
Building (net)	165,000
Equipment (net)	350,000
Total assets	1,086,000
Accounts payable	87,000
Notes payable	80,000
Taxes payable	60,500
Total CLs	227,500
Long-term loan (due 2017, 5% interest)	100,000
Common stocks	400,000
Retained earnings	358,000
Total liabilities and owners' equities	1,086,000

Example 7.5

Innovative Products is a company that has enjoyed a high growth rate in recent years. Its growth has been largely financed by the retained earnings that belong to the common stockholders (see Table 7.10).

For the last three years, the company has earned an average annual net income of $75,000, after having paid an annual interest of $8,000 and the annual taxes of $50,000. The company's tax rate is 40%.

Company management is considering the strategy of raising $750,000 to double its production volume. Of this amount, $500,000 would be used to (1) build an addition to the current office building, (2) purchase new IT equipment, and (3) install an advanced Enterprise Resources Planning (ERP) software system. The remaining amount would be needed for working capital to add inventories and to enhance marketing and selling activities.

Market research suggests that, despite a doubling of the company's sales volume, the product price can be kept at the current level. The EBIT is projected to be $275,000.

Two specific financing options are to be evaluated closely:

1. Sell enough additional stock at $30 per share to raise $750,000.
2. Sell 20-year bonds at 5% interest, totaling $500,000.

Determine which financing option is to be favored from the standpoint of earning per share.

Answer 7.5

Earning per share is defined as the company's net income divided by the number of outstanding common stocks. To compare the earning per share data for these two financing options, the income statement must be constructed as in Table 7.11. The following explanations may be helpful:

TABLE 7.11

Income Statement of Innovative Products (2014)

	Present Operation	Option 1	Option 2
	No Financing ($)	**Equity Financing ($)**	**Equity and Debit Financing ($)**
EBIT	133,000	275,000	275,000
Interest	8,000	8,000	25,000
Taxable income	125,000	267,000	250,000
Taxes (40%)	50,000	106,800	100,000
Net income	75,000	160,800	150,000
Outstanding shares of stocks	400,000	425,000	410,000
Earning per share (EPS)	0.1875	0.3769	0.3658

1. From the known values of net income ($75,000), tax rate (40%), and interest payment ($8,000) of the present operation, the EBIT is calculated to be $133,000.
2. For the present operation, the number of outstanding common stock is 400,000, because the common stock (usually at the par value of $1) is listed as $400,000 in the company's balance sheet (see Table 7.10).
3. For Option 1 and Option 2, the EBIT is known to be $275,000.
4. For Option 1, the interest charge remains at $8,000, but the number of outstanding stocks is increased to 425,000.
5. For Option 2, the interest charge is increased by $25,000 annually due to the new loan. However, the old loan is being paid off, reducing the annual interest payment by $8000. Thus, the net interest payment is $25,000 per year.
6. For Option 2, the number of outstanding stocks is increased to 410,000.

   Based on this analysis, the earning per share of Option 1 is larger than those of the present operation and Option 2. Equity financing is to be preferred.

7.6.3 Weighted Average Cost of Capital

WACC is a very important cost figure for any company (Pratt et al. 2014). It is defined as

$$\text{WACC} = K_e\left(\frac{E}{V}\right) + K_d\left(1-t\right)\left(\frac{D}{V}\right) \tag{7.4}$$

where:

- D = debt (long-term loans, corporate bonds, etc.) (dollars)
- E = equity (stocks) (dollars)
- t = corporate tax rate (percent)
- V = $E + D$ (dollars)
- K_e = cost of equity capital (e.g., 0.15–0.18)
- K_d = cost of debt capital (e.g., 0.08 = yield to maturity [YTM] rate for bonds, plus cost associated with lost growth opportunity)

In general, an increase in leverage (e.g., adding more debts) reduces the firm's WACC. This is due to the tax deductibility of interest payments associated with the debt. For many companies, WACC is typically in the range of 8%–16%.

7.6.4 Effect of Financial Leverage

Financial leverage denotes the use of debts in financing corporate projects. A measure of financial leverage is given by the leverage ratio D/V. The company is said to be highly leveraged if its leverage ratio is more than 0.5 (Mathis 2014).

Leverage ratio is known to have an impact on both the variability of reportable earning per share and the return on equity values. This is illustrated by the following example.

Assume that the total assets of a company are \$1000. These assets may be financed 100% by equity (Case A) or by a combination of 40% equity and 60% debt (Case B). It is further assumed that under normal circumstances the company's EBIT is \$240. The EBIT value may be reduced to \$60 under bad economic conditions, but it could be increased to \$400 under good conditions. The corporate tax rate is assumed to be 50%. There is no interest payment in Case A. However, \$48 must be paid in Case B as an interest charge, which is tax deductible. The net incomes in these cases are different. The earning per share and return on equity data reported out by the company vary accordingly (see Table 7.12).

Under normal economic conditions, the earning per share is 1.20 in Case A (no debt) and 2.40 in Case B (with debt). Thus, companies engaged in debt financing will be able to report out higher earnings per share data than others that carry no debt, assuming everything else being equal.

In the absence of leverage (no debt, Case A), the earning per share varies from 0.3 to 2.0 and the return on equity from 3.0 to 20 (both from 25% to 167%). When the company engages in debt financing, these same ratios vary more widely from 0.15 to 4.40 and from 1.5 to 44.0 (both from 6.25% to 183%), respectively. Financial leverage compounds the variability of companies' financial performance.

TABLE 7.12

Impact of Leverage on EPS and ROE

	Case A			Case B		
	Bad	**Normal**	**Good**	**Bad**	**Normal**	**Good**
Assets		1000			1000	
Debt		0			600	
Equity		1000			400	
Leverage ratio (%)		0			60	
EBIT	60	240	400	60	240	400
Interest (8%)	0	0	0	48	48	48
Taxable income	60	240	400	12	192	352
Tax (50%)	30	120	200	6	96	176
Net income	30	120	200	6	96	176
Number of shares	100	100	100	40	40	40
EPS	0.3	1.2	2	0.15	2.4	4.4
ROE (%)	3	12	20	1.5	24	44

Notes: When ROE exceeds interest (cost of debt), leverage has a favorable impact on EPS, and vice versa. Financial leverage increases the variability of EPS positively as well as negatively.

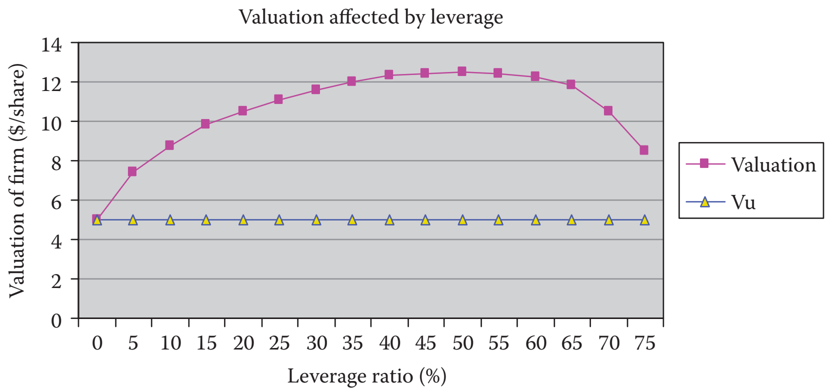


FIGURE 7.2
Optimum leverage.

7.6.5 Optimum Leverage

The correct selection of the amount of leverage (i.e., debts) is of critical importance to the economic health of a firm. Incurring an excessive amount of debt (high leverage) will push the company to generate cash for meeting the interest payments, skimp on quality, keep inventory low, invest little in maintenance and capital expenditures, and make short-term-oriented decisions, since the company is not able to capitalize on future growth opportunities. On the other hand, if the debt level is too low (low leverage), the firm does not feel any real pressure to be as efficient as possible (e.g., management will tend to waste resources, tolerate excessive scrap, commit capital expenditures loosely, and initiate R&D indiscriminately) and will suffer from having a higher cost of capital than otherwise because it could not take advantage of the tax deductibility of interest payments on debt.

Most firms attempt to assume an optimum amount of leverage. This is because, as the leverage exceeds the optimum level, the valuation of the firm experiences a reduction due to (a) the cost of bankruptcy, (b) agency costs (e.g., lawyers, courts, and others), and (c) preemptive costs (i.e., loss of growth opportunities). Figure 7.2 illustrates such a leverage optimum, where Vu is the value of the firm with no leverage.

7.7 Capital Assets Valuation

Financial management deals with three general types of capital assets valuation problems: assets in place (operations), opportunities (R&D and marketing), and acquisitions or joint ventures.

Capital budgeting problems related to *assets in place* are those that deliver a predictable string of cash flows in the immediate future. Examples include building a new plant facility, developing new products, and entering a new regional market. Sometimes these problems are grouped under the heading of operations, as investment in operations usually leads to immediate cash flows. Problems related to *opportunities* arise from decisions that do not generate an immediate flow of cash but preserve a likelihood that future gains may be realized. Examples include R&D and marketing efforts. The third type of problems is

TABLE 7.13

Recommended Capital Assets Valuation Methods

Valuation Problems	Recommended Methods	Alternative Methods
1. Assets in place (operations)	DCF (based on WACC)	Multiples of sales, cash flows, EBIT or book value, Monte Carlo simulations
2. Opportunities (R&D, marketing)	Simple option theory	Decision tree, complex option pricing, simulations
3. Equity claims	Equity cash flow	Multiples of net income, P/E ratios, DCF (based on WACC minus debt), simulations

related to *acquisition*, *joint venture*, creation of supply chains, and others, all of which may require the company to participate in equity investment and to share future equity cash flows with its business partners.

Generally speaking, each of these types of valuation problem is best handled by different valuation methods. Larrabee and Voss (2012) suggest a list of recommended methods, as shown in Table 7.13.

7.7.1 Operations: Assets in Place

There are several evaluation methods currently in use to assess capital projects in the investment category of operations.

7.7.1.1 Discount Cash Flow (Based on WACC)

Today, most companies are using the discounted cash flow (DCF) method to determine the net present value of an operation with assets in place and assigning WACC to be the discount factor:

$$\mathrm{NPV} = -P + \sum_{t=1}^{N} \frac{C_t}{(1+\mathrm{WACC})^t} + \frac{\mathrm{SV}}{(1+\mathrm{WACC})^N} \tag{7.5}$$

where:

- NPV = net present value (dollars)
- P = initial capital investment (dollars)
- C_t = cash flows = future net benefits (dollars)
- SV = salvage value recovery at end of project's useful life (dollars)
- N = total number of periods (year)
- WACC = weighted average cost of capital (fraction)

NPV is equal to the present value of all future net benefits (e.g., income minus relevant costs), plus discounted salvage value recovery, if any, and minus the initial investment capital. It represents the net financial value added to a firm by a given capital investment. Projects with large positive NPV values are favored. This method is sometimes called the *DCF (based on WACC) analysis*, as it is based on the use of the weighted cost of capital as the all-important discount factor.

Companies accept capital projects if the NPV is greater than zero, meaning that the initiation of such projects leads to a net positive value added to the companies.

7.7.1.2 Internal Rate of Return

A popular variation of DCF (based on WACC) is the internal rate of return (IRR). When applying Equation 7.5 to evaluate projects, IRR is the discount rate that is realizable when the present values of all discounted cash flows balance the initial investment (NPV equals zero). IRR represents the reinvestment rate, which is held constant over the duration of the project. For example, assuming no salvage value, the IRR of a $10,000 investment that yields a revenue of $5,000 per year for three years is 23.35%.

In general, companies specify hurdle rates that must be met or exceeded by the IRRs of all capital projects acceptable to specific regions (e.g., China, India, Brazil, or Russia). By adjusting the hurdle rate according to regional conditions related to market, economy, and risk level of the local environment for a specific period involved, companies exercise detailed control over the capital investment criteria. The hurdle rates are typically three to four times WACC in value.

The major deficiency of IRR is the basic underlining assumption that the interim cash flows will be reinvested at the same high rates of return. This may not be realistic in practice. In contrast, NPV is more realistic, in that its calculation requires only the assumption that a company can earn its cost of capital (e.g., WACC) on interim cash flows.

7.7.1.3 Multipliers

Another method to estimate the proper capital investment in a project is to use numerical multipliers that are based on historical data. Specifically, average multipliers are defined for use in conjunction with commonly available financial data such as sales, book value, EBIT, and cash flow.

In general, the financial data of many publicly held companies in various industries are widely available in THE literature, including Standard & Poor's Industry surveys and Value Line Industrial surveys. The sales figures of numerous companies are readily obtained, and their relationship with company assets is typically recorded as the *asset turn ratios* (see Section 7.4.1). The reciprocal of this ratio is a multiplier that, when used together with the known sales figure, provides a rough estimate of the company's asset value.

For the XYZ Company described in Tables 7.8 and 7.9, the sales to total asset ratio for the year 2013 is 0.856(= 395,000/461,500). The reciprocal of this number is 1.168, which is the sales multiplier to determine assets. If a sufficient number of other companies in the same industry are surveyed, the resulting average industry-based multiplier can be used to generate a preliminary estimate of the assets employed to produce known sales revenue.

To determine the capital investment value of a plant expansion, new product development, and other products, the company's existing total sales to total asset ratio may serve as a good yardstick to ascertain a reasonable capital investment level, but only if the project outcome in terms of future sales can be estimated.

How much debt should the company incur to finance a specific project? The *debt to asset ratio* is linked to the debt-to-equity ratio (see Section 7.4.1). For the XYZ Company described in Table 7.9, the debt to asset ratio for 2013 is 0.18(= 84,500/461,500). Again, if an industrial average is found for this multiplier, it can serve as a useful tool to estimate a reasonable debt level for a project on the basis of its known asset value.

Yet another multiplier is related to EBIT. This multiplier is estimated to be 14.49 for the XYZ Company in 2013, based on the EBIT to asset ratio of 0.051(= 23,500/461,500) evident in Tables 7.8 and 7.9.

The use of some of these multipliers in combination is likely to generate figures that can serve as an acceptable ballpark estimate of the required investment for a new project.

7.7.1.4 Monte Carlo Simulations

Monte Carlo simulations refer to a sampling technique that processes input data presented in the form of distribution functions. All input variables are simultaneously varied within each of their respective ranges, as defined by their distribution functions. The mathematical operations (e.g., addition, subtraction, multiplication, and division) of a given cost model are readily specified in spreadsheet programs (Smith 2000). On activating a suitable risk analysis software program, Monte Carlo simulations produce one or more outputs that are also in the form of distribution functions (Brandimarte 2014) (see Section 6.4.2).

In evaluating operations, Monte Carlo simulations may be usefully applied to the DCF (based on WACC) method. All future net cash flows and discount rates are modeled by distribution functions (e.g., Triangular or Gaussian), as they are expected to vary within ranges. The DCF (based on WACC) equation is readily modeled in a spreadsheet program. As the sole output, the NPV will also vary between a lower and an upper bound. The following results will be helpful to capital budgeting decision-makers:

1. The maximum probability at which the NPV is projected to be negative
2. The probability at which the NPV is projected to exceed a given value (e.g., $10 million)
3. The standard deviation of the NPV output
4. The minimum NPV
5. The maximum NPV

Monte Carlo simulations are also applicable to the calculation of IRR for the evaluation of operations.

7.7.2 Opportunities: Real Options

The second category of valuation problems is related to opportunities such as R&D and marketing projects. These problems do not lend themselves to DCF analyses in the absence of projected future cash flows. If there is no cash flow, there can be no net positive present value. Financial analysts and researchers in the literature recommend that the *European simple call option* method be used to price these opportunities.

Option is a common tool frequently used for trading securities in the financial markets. There are *call* and *put* options. A *call option* provides its holder with the right, but not the obligation, to buy 100 shares of an underlying company (e.g., Apple, IBM, or General Electric) by a certain expiration date (typically three months from the present) at a specific price (*strike* or *exercise* price). The holder pays a fee, or premium, to buy the call option, which he or she may exercise on any business day leading up to and including the contract expiration date. A *put option* gives its holder the right, but again not the obligation, to sell 100 shares of stocks within a period of time at a predetermined strike price. Investors who predict that the stock price of a given company is going to decline in the future will want to sell the stocks today and buy a call option to recover the stocks at a lower price in the future. The premium for an option is dependent on five factors: (1) current stock price,

TABLE 7.14

Equivalence of Call Options

Financial Calls	Real Calls
Current stock price	Underlying asset value
Length of contract	Length of time to invest
Volatility	Volatility of future project value
Strike price	Capital investment for the project
Current bank interest	Cost of equity capital

(2) strike price, (3) length of option contract, (4) stock price volatility, and (5) current opportunity cost (e.g., bank interest).

For the purpose of evaluating capital project opportunities, the European simple call option is more appropriate, in that the call option can be exercised only on the expiration date specified in the contract and no sooner. Table 7.14 shows the equivalence between financial calls and real calls.

Companies with new technologies, product development ideas, defensive positions in fast-growing markets, and access to new markets have valuable opportunities to explore. When dealing with opportunities, three possible scenarios exist: (1) to invest immediately, (2) to reject the opportunity right away, and (3) to preserve the option of investing in the opportunity at a later time (Ursone 2015; Capinski and Kopp 2012).

This problem may be studied by using the Black–Scholes option pricing model (BSOPM) (Black and Scholes 1973), which is defined as

$$C = V\left[N(d)\right] - e^{-rT} \times \left[N\left(d - \sigma\sqrt{T}\right)\right] \tag{7.6}$$

$$d = \frac{\ln(V/X) + T\left(r + \sigma^2/2\right)}{\sigma\sqrt{T}} \tag{7.7}$$

where:

C = option price
V = current value of the underlying asset
X = exercise price of the option
σ = annual standard deviation of the returns on the underlying asset
r = annual risk-free rate
$N(d)$ = cumulative standard normal distribution function evaluated at d
$\ln(x)$ = natural log function of x
T = time to expiration of the option (years)

Table 7.15 exhibits the representative data of the $N(d)$ function.

Investment opportunities related to the initiation of new R&D projects or marketing programs may be cast into the format of options when exploring the possibilities (1) yes, invest now, (2) no, reject the proposal, and (3) buy time to reconsider the same project in the near future, as external and internal conditions may change. BSOPM could be applied to offer an estimate of the maximum expenditure the company should consider, which could be usefully applied to foster the third option (e.g., hiring more R&D experts, understanding R&D efforts of competitors, acquiring additional market intelligence, securing specific competitive information, consulting on industrial trends, the future needs of customers, or the possibility of new capital formation).

TABLE 7.15

Values of Cumulative Normal Distribution Function

D	*N(D)*	*D*	*N(D)*	*D*	*N(D)*
−3.00	0.0013	−1.00	0.1587	1.00	0.8413
−2.90	0.0019	−0.90	0.1841	1.10	0.8643
−2.80	0.0026	−0.80	0.2119	1.20	0.8849
−2.70	0.0035	−0.70	0.2420	1.30	0.9032
−2.60	0.0047	−0.60	0.2743	1.40	0.9192
−2.50	0.0062	−0.50	0.3085	1.50	0.9332
−2.40	0.0082	−0.40	0.3446	1.60	0.9452
−2.30	0.0107	−0.30	0.3821	1.70	0.9554
−2.20	0.0139	−0.20	0.4207	1.80	0.9641
−2.10	0.0179	−0.10	0.4602	1.90	0.9726
−2.00	0.0228	0.00	0.5000	2.00	0.9772
−1.90	0.0287	0.10	0.5398	2.10	0.9821
−1.80	0.0359	0.20	0.5793	2.20	0.9861
−1.70	0.0446	0.30	0.6179	2.30	0.9893
−1.60	0.0548	0.40	0.6554	2.40	0.9918
−1.50	0.0668	0.50	0.6915	2.50	0.9938
−1.40	0.0808	0.60	0.7257	2.60	0.9953
−1.30	0.0968	0.70	0.7580	2.70	0.9965
−1.20	0.1151	0.80	0.7881	2.80	0.9974
−1.10	0.1357	0.90	0.8159	2.90	0.9981

Example 7.6

If \$1 million is invested immediately, there will be a loss of \$100,000 due to the current economic conditions and marketing environment. However, if the company waits for two years, things may be different. What should the company do, assuming that the current risk-free rate is 7% and the project volatility is 0.3?

Answer 7.6

The problem may be studied by using BSOPM. Let us define the following equivalents:

$$\sigma = 0.3$$

$$r = 0.07$$

$$X = \$1{,}000{,}000$$

$$V = \$900{,}000$$

$$T = 2$$

From Equation 7.7,

$$d_1 = \frac{\left\{\ln\left(900{,}000 / 1{,}000{,}000\right) + 2\left(0.07 + 0.3^2/2\right)\right\}}{0.3\sqrt{2}} = 0.2938$$

$$d_2 = 0.2938 - 0.3 \times 1.41456 = -0.1306$$

From Table 7.15, we get by interpolation

$$N(0.2938) = 0.6155$$

$$N(-0.1356) = 0.4462$$

From Equation 7.6, the option price becomes

$$C = 900,000 \times 0.6155 - \exp(-0.07 \times 2) \times 1,000,000 \times 0.4462$$
$$= \$166,042$$

Now, the company has the alternative of investing \$166,042 to preserve investment opportunities for two years in addition to deciding for or against it right away. If this option is preserved, additional information that will cause a change in the underlying asset value may become available during the ensuing two years. The company may still decide not to invest in two years, but preserving the option to invest remains a valuable alternative.

7.7.3 Acquisitions and Joint Ventures

When companies are being considered as candidates for acquisition, the evaluation of the assets of the target companies becomes critically important. A number of methods are practiced to assess the value of a company (McKinsey et al. 2015; Vernimmen et al. 2014).

The value of a company is defined by its equity and debt:

$$V = E + D \tag{7.8}$$

where:
- V = firm's value in the market
- E = equity (stocks)
- D = debt outstanding (bonds, loans, etc.)

The company management continues to maximize the candidate firm's value for its shareholders. Two factors may affect this value maximization attempt: (1) *takeover bids* (when the acquiring firms are enticed to pay a higher than normal premium to absorb the acquisition candidates) tend to raise the stock price; and (2) *stock options* (rights to buy stock at a fixed price awarded to the company's management personnel and new hires) tend to dilute the shareholder value.

Example 7.7

XYZ Company is considering the acquisition of Target Company, a smaller competitor in the same industry. The income statement of Target Company is displayed in Table 7.16. As a stand-alone company, its sales, CGS, depreciation, selling, and administrative expenses are all projected to increase by 4% per year.

To maintain the projected sales growth of Target Company, XYZ Company must make additional working capital investments (see Table 7.16).

1. Assuming a 10% discount rate, what is the maximum price XYZ Company should be willing to pay for this acquisition if it is to be run as a stand-alone subsidiary of XYZ Company?

TABLE 7.16

Income Statement of Target Company (2010–Future)

	2010	2011	2012	2013	2014	Growth to Infinity (%)
	(Dollars in Thousands)					
Sales	61,000	63,440	65,978	68,617	71,361	4
Cost of goods sold	29,890	31,086	32,329	33,622	34,967	4
Depreciation	4,000	4,160	4,326	4,499	4,679	4
Selling and administrative	21,010	21,850	22,724	23,633	24,579	4
IT services	0	0	0	0	0	4
EBIT	6,100	6,344	6,598	6,862	7,136	4
Tax (35%)	2,135	2,220	2,309	2,402	2,498	4
EBIAT	3,965	4,124	4,289	4,460	4,638	4
Cash flow	7,965	8,284	8,615	8,960	9,318	4
Additional investments						
Working capital	8,000	8,320	8,653	8,999	9,359	4

2. XYZ Company could also integrate Target Company into its existing corporate IT operations. Web-based customer services, inventory management, order processing, and other activities can be readily added to cut down the required working capital by 50% from its stand-alone values. There is, however, an increased IT service charge of $1 million for the first year, and this charge increases by 4% per year. Again, assuming a 10% interest rate, what is the maximum price XYZ should pay for Target Company under the integration scenario?

Answer 7.7

For estimating the present values of cash flows for the period 2010 to infinity, the computations illustrated in Table 7.17 are needed. In Table 7.17, A denotes a constant but unknown cash flow defined at the beginning of year 2010.

The present value of cash flow (at the beginning of year 2010) in Table 7.18 is then calculated by the equation $A + A(1 - r)/r$, where $A = 7965/1.1 = 7240.91$ and $r = 0.05454545$.

TABLE 7.17

Present Value of Cash Flows in 2010 (Growth Rate = 4% and Discount Rate = 10%)

	2010	2011	2012	2013	Infinity
Cash flow	A	$A(1.04)$	$A(1.04)^2$	$A(1.04)^3$	
Present value (2010)	$A/(1.10)$	$A(1.04)/(1.10)^2$	$A(1.04)^2/(1.10)^3$	$A(1.04)^3/(1.10)^4$	
Replacement		$A(1 - r)$	$A(1 - r)^2$	$A(1 - r)^3$	
$r =$	0.05454545				
Let		$C = (1 - r) + (1 - r)^2 + (1 - r)^3\_(1 - r)^4 + \dots + (1 - r)^n$			
		$C(1 - r) = (1 - r)^2 + (1 - r)^3 + (1 - 3)^4 + \dots + (1 - r)^{(n+1)}$			
		$C - C(1 - r) = (1 - r) - (1 - r)^{(n+1)}$			
		$C = (1 - r)/r$ as n approaching infinity			
PV of all future cash flow at the start of 2010		$A/1.10 + A(1 - r)/r/1.10 = A/r/(1.10)$			
PV (cash flow) =	132,750				
PV (working capital) =	133,333				

TABLE 7.18

Income Statement of Target Company (Stand-Alone Subsidiary: Thousands of Dollars)

	2010	2011	2012	2013	2014	Growth to Infinity (%)
Sales	61,000	63,440	65,978	68,617	71,361	4
Cost of goods sold	29,890	31,086	32,329	33,622	34,967	4
Depreciation	4,000	4,160	4,326	4,499	4,679	4
Selling and administrative	21,010	21,850	22,724	23,633	24,579	4
IT services	0	0	0	0	0	4
EBIT	6,100	6,344	6,598	6,862	7,136	4
Tax (35%)	2,135	2,220	2,309	2,402	2,498	4
EBIAT	3,965	4,124	4,289	4,460	4,638	4
Cash flow	7,965	8,284	8,615	8,960	9,318	4
PV (cash flows)	132,750					4
Additional investments						
Working capital	8,000	8,320	8,653	8,999	9,359	4
PV (WC charge)	$133,333					
(A) NPV of target company	(583.26) (not to acquire)					

The same procedure is to be applied to determine the present value of required working capital, which turns out to be $133,333 (see Table 7.18).

Since the NPV of Target Company, as a stand-alone operation, is negative, it does not justify being acquired by XYZ Company.

On the other hand, if XYZ integrates Target Company into its IT operations, the value of this target company is significantly improved, as displayed in Table 7.19.

Under the integration scenario, Target Company is worth about $48 million. Any purchase price below this figure will denote a net gain for XYZ Company.

TABLE 7.19

Income Statement of Target Company (Integrated Operations: Thousands of Dollars)

	2010	2011	2012	2013	2014	Growth to Infinity (%)
Sales	61,000	63,440	65,978	68,617	71,361	4
Cost of goods sold	29,890	31,086	32,329	33,622	34,967	4
Depreciation	4,000	4,160	4,326	4,499	4,679	4
Selling and administrative	21,010	21,850	22,724	23,633	24,579	4
IT services	1,000	1,040	1,082	1,125	1,170	4
EBIT	5,100	5,304	5,516	5,737	5,966	4
Tax (35%)	1,785	1,856	1,931	2,008	2,088	4
EBIAT	3,315	3,448	3,586	3,729	3,878	4
Cash flow	7,315	7,608	7,912	8,228	8,558	4
PV (cash flows)	121,916					4
Additional investments						
Working capital	4,000	4,160	4,326	4,499	4,679	4
PV (WC charge)	$73,333					
(B) NPV of integrated company	$48,583 (to bid for no more than $48.00 million)					

7.7.3.1 Common Stock Valuation Model (Dividend Valuation Model)

The stock price of the acquisition target company depends on the dividend stream it is able to generate. The *dividend valuation model* offers an estimate of the acquisition candidate's stock price as the sum of the present values of its future dividends:

$$P_o = \sum_{t=1}^{\infty} \frac{D_t}{(1+r)^t} \tag{7.9}$$

where:

P_o = equity price
D_t = dividend payout (DPS) per period
$r = K_e$ = cost of equity capital incurred by the firm
Upper limit = infinite (going concern)

Two special cases may be considered:

1. *Constant dividend*

   If $D_t = D_o$ = constant, then

$$P_o = \frac{D_o}{r} = \text{capitalized value of dividend} \tag{7.10}$$

   The stock price P_o is equivalent to a single present value that is capable of producing a stream of constant dividends of value D_o indefinitely. (The derivation of this closed-form solution is included in Appendix 7.C.)

2. *Finite holding period*

   For investors who hold a given stock for only N periods and plan to sell the stock at the price P_n thereafter, the stock price may be calculated as

$$P_o = \sum_{t=1}^{N} \frac{D_t}{(1+r)^t} + \frac{P_n}{(1+r)^N} \tag{7.11}$$

where:

r = effective rate of return required by the market of the firm's stock, equal to the cost of equity capital incurred by the firm (K_e)
P_n = investment recovery at the end of N periods

Once the stock price is known, the total value of the acquisition candidates is then equal to the stock price multiplied by the outstanding number of its stocks.

7.7.3.2 Dividend Growth Model

If the target company is capable of paying out dividends that grow at an annual rate of g percent, then its stock price is calculated as the capitalized dividend value at a rate equal to the cost of capital minus the dividend growth rate:

$$P_o = \frac{D_1}{(K_e - g)} \tag{7.12}$$

where:

g = growth rate of dividend per share (percent)
K_e = cost of equity capital (note: $K_e > g$)
D_1 = dividend for the next period (dollars/share)

(The derivation of this equation is given in Appendix 7.D.)

The growth rate of annual dividend is calculated by the equation

$$g = (1 - b)\ \text{ROE} \tag{7.13}$$

where:

ROE = net income/average equity capital
b = payout ratio of dividend = dividend payout/net income
$1 - b$ = retained dividend ratio = dividend retained/net income

In Equation 7.13, the assumption is made that the company management is capable of applying the retained earnings to foster dividend growth in the current year at the same rate as that of the ROE that was accomplished by the company in the previous fiscal year.

7.7.3.3 Modified Earning Model

The stock price of a company that reinvests retained earnings to generate dividend growth is delineated by the equation

$$P_o = \frac{\text{EPS}_1}{K_e} + \text{PVGO} \tag{7.14}$$

where:

EPS_1 = earning per share in the next period
K_e = cost of equity capital
PVGO = present value of growth opportunities

Now, EPS_1/K_e is the capitalized value of EPS, and PVGO is the net present value of all returns (on the per share basis) generated by having reinvested the retained earnings at the rate of ROE. Specifically,

$$\text{PVGO} = \frac{\text{EPS}_1 (1 - b)(\text{ROE} - K_e)}{K_e (K_e - g)} \tag{7.15}$$

Typically, growth stocks have large PVGO values that arise from the reinvestment of continuously increased earnings at the rate of

$$g = (1 - b)\ \text{ROE} \tag{7.16}$$

(For a derivation of Equation 7.15, see Appendix 7.E.)

Example 7.8

The company's stock is selling now at \$50 per share. Its expected dividend next year is \$2.00 per share. A 20% annual growth of dividend is anticipated for the next three years. From the fourth year on, its dividend growth rate will be reduced to only 6% annually. What is the expected long-term rate of return (R) from buying this stock at \$50?

Answer 7.8

On the basis of the dividend model, we would formulate the following equation for evaluating the overall rate of return:

$$P_o = \frac{\text{Div}_1}{(1+R)} + \frac{\text{Div}_2}{(1+R)^2} + \frac{\text{Div}_3}{(1+R)^3} + \frac{\text{Div}_4}{(1+R)^4} + \frac{\text{Div}_5}{(1+R)^5(R-g)}$$

$$50 = \frac{2}{(1+R)} + \frac{2(1.2)}{(1+R)^2} + \frac{2(1.2)^2}{(1+R)^3} + \frac{2(1.2)^3}{(1+R)^4} + \frac{2(1.2)^3(1.06)}{(1+R)^5(R-0.06)}$$

By trial and error, $R = 0.11153$. The long-term rate of return of this stock is 11.153%.

Example 7.9

The company expects a total sales revenue of \$20 million and a total cost, including tax, of \$15 million in the forthcoming year. During the subsequent five years (e.g., Year 2 to Year 6), the revenues and costs will increase by 25% per year, and all profits will be reinvested into the business. Thereafter, the company's growth will decrease to only 5% per year, and the company will need to reinvest only 40% of its profits.

If the company is offered \$75 million in cash by a major competitor, is this a fair acquisition price, assuming the cost of capital is 12%?

Answer 7.9

Stock price is the present value of expected future dividend. On the basis of this model, we have

$$P_o = \frac{\text{Div}_1}{(1+R)} + \frac{\text{Div}_2}{(1+R)^2} + \frac{\text{Div}_3}{(1+R)^3} + \frac{\text{Div}_4}{(1+R)^4} + \frac{\text{Div}_5}{(1+R)^5} + \frac{\text{Div}_6}{(1+R)^6} + \frac{\text{Div}_7}{(1+R)^7(R-g)}$$

$$\text{Div}_1 = \text{Div}_2 = \text{Div}_3 = \text{Div}_4 = \text{Div}_5 = \text{Div}_6 = 0.0$$

$$\text{Div}_7 = (20-15)(1.25)^5(1.05)(1-0.4) = \$9.613 \text{ million}$$

For the sixth year,

$$g = (1-b)\ \text{ROE};\ \ 0.25 = (1-0)\ \text{ROE}$$

$$\text{ROE} = 0.25$$

For the seventh year,

$$g = (1-b)\ \text{ROE} = (1-0.6)\ 0.25 = 0.1$$

$$P_o = \frac{9.613}{(1+0.12)^7 (0.12-0.1)} = \$217.4 \text{ million}$$

The offered acquisition price is much too low, and the offer should be rejected.

7.7.3.4 Equity Cash Flows

For the valuation problems related to joint ventures and partnerships, ownership claims and equity cash flows must be evaluated. Financial specialists are typically involved in evaluating such problems by using sophisticated computer programs and models. For detailed discussions of this type of evaluation, see Luehrman (1997). Other advanced corporate finance issues are discussed by Damodaran (2014).

Capital budgeting is a managerial responsibility related to the company's capital investments. Capital budgeting decisions are made on the basis of certain rational decision criteria. Engineering managers are advised to acquire the necessary background knowledge to become effective contributors to such decision-making processes.

7.8 Conclusion

This chapter introduces the basic accrual principle of financial accounting and discusses the workings of income statements, balance sheets, and funds flow statements, with explanations of all applicable accounting terms. Also pointed out are the ways in which contributions by engineering managers are recorded in these financial statements.

Ratio analysis uses the financial data contained in these statements to assess companies' financial health. EVA is described as an upgraded method of reporting the true financial value created by a company, a unit, or a specific project.

The shortcomings of ratio analysis are outlined, and a broad-based system of measurement metrics (the balanced scorecard) is illustrated. An adoption of this broad-based metrics system by corporate America will likely shift corporate management's attention from being predominantly focused on short-term financial results to a balanced emphasis on corporate long-term growth. This is possible with the use of metrics that address important competitive factors such as customer satisfaction, continuous improvement of internal business processes, and innovation for growth. As such broad-based measurement metrics become widespread, the critical contributions made by engineering managers will be increasingly recognized and rewarded.

This chapter also reviews the basic elements of financial management: raising and applying investment capital. Equity and debt financing are the two most common ways of obtaining financing. There are costs involved in each: the cost of equity capital and the cost of debt capital.

There are different types of capital projects in which a company might invest: operations (assets in place), opportunities (R&D and marketing), acquisitions, and joint ventures.

Different evaluation methods are used for these capital projects. For example, DCF (based on WACC), IRR, multipliers, and Monte Carlo simulations are useful for evaluating operations. Option pricing is suitable for evaluating opportunities for which there are no predictable cash flows. Acquisitions and joint ventures are advanced financial topics, the evaluation of which should be deferred to knowledgeable financial specialists on the subject.

Benjamin Disraeli said, "As a general rule, the most successful man in life is the man who has the best information." Financial information is part of the best information STEM professionals should have.

Engineering managers are advised to become well prepared to actively participate in the company's capital budgeting process by becoming familiar with the sources and costs of capital as well as the evaluation criteria adopted for capital budgeting. Doing so will enable them to constantly bring forth and screen useful projects and valuable opportunities (including risks assessment) and to be in a position to initiate winning capital project proposals on a timely basis.

QUESTIONS

1. Michele Brown started up a new consulting firm to offer design and testing services to industries. During the first three months of its operation, the firm has recorded a number of transactions, shown as follows:
   a. Michele Brown initiated the business by investing $35,000 in cash; $1,200 for office equipment; and $23,500 for instrumentation.
   b. Land for an office site was purchased for $17,500: $5,000 paid in cash and a promissory note signed for the balance.
   c. A prefabricated building was purchased for $7000 cash and moved onto the land for use as an office.
   d. The premium of $800 was paid on an insurance policy.
   e. A consulting project for Central Construction was completed, and $900 was collected.
   f. Additional test equipment costing $10,000 was purchased for $2,000 in cash, and a note payable for the balance was signed.
   g. A consulting project was completed on credit for Eastern Manufacturing for $1200.
   h. Office supplies were purchased on credit for $300.
   i. A bill was received for $250 and recorded as an account payable for rent on a special machine used for the Western Technologies project.
   j. A project for Superior Design was completed on credit for $1000.
   k. Cash was received from Eastern Manufacturing for the consulting project they received on credit.
   l. The wage of engineers, $5000, was paid.
   m. Office supplies purchased earlier (for $300) were paid for.
   n. Cash of $125 was paid for repairs to test equipment.
   o. The company president, Larry Brown, wrote a $65 check on the bank account of the consulting firm to pay for repairs to his personal automobile, which is not used for business purposes.
   p. The wage of the office workers, $3000, was paid.
   q. The maintenance expenses of the instruments, $300, was paid.

   Open the following T-accounts: cash, accounts receivable, prepaid insurance, test equipment, building, land, notes payable, accounts payable, office supplies, Larry Brown—capital, Larry Brown—withdrawals, sales revenue, instrument maintenance expense, test equipment rental expense, office equipment, instrumentation, and test equipment repairs.

Record the transactions by entering debits and credits directly into the accounts. Use the transaction letters to identify each debit and credit entry. What is the cash account balance at the end of this three-month period?

2. As the vice president of engineering of the Best Company in Buffalo, you need to make a decision regarding how a new product is to be manufactured. You have been offered two specific proposals. Proposal A is to set up an assembly operation in-house and to outsource the production of all subassemblies and parts to supply chain partners. This proposal would need a front-end investment of $2,000,000 for the assembly operations, an investment of $300,000 for the product design and development efforts, and another $100,000 for managing and coordinating the supply chain partners. The projected net profits for the products manufactured by this method are $0, $300,000, $600,000, $900,000, $1,200,000, and $600,000 in the first, second, third, fourth, fifth and sixth year, respectively. There is no salvage value of the assembly equipment at the end of the sixth year, at which time the sales of this product will be terminated. Interest is at 5.0%.

   Proposal B is to build a production facility to manufacture all subassemblies and assemble the products in-house. This proposal would need a front-end investment of $3,000,000, which includes facility, equipment, engineering, and all other required efforts. The projected net profits for the products manufactured by this method are $200,000, $400,000, $800,000, $1,200,000, $1,000,000, and $600,000 for the first, second, third, fourth, fifth, and sixth year, respectively. There is a salvage value of $400,000 of the facility at the end of the sixth year. Interest is also at 5%.

   Which proposal should you accept, and why?

3. The ABC Company supplies products to a number of original equipment manufacturers (OEMs). It employs 5000 mostly unionized workers and generates about $2.2 billion in revenue annually. In 2012, it won an "Excellence Award" from one of its major client companies for having supplied an OEM product at the quality level of 10 defects per million in three consecutive years, thereby exceeding the specific target of 15 defects per million set by this client.

   However, the corporate parent of the ABC Company was less than happy with its financial performance. It declared this subsidiary a "Troubled Operation" in 2013, giving notice that if its business performance did not improve within a certain time frame, the ABC Company would be closed down or divested. The specific financial targets set by the corporate parent consisted of (1) NOPAT to sales ratio at 5%, (2) EBIT to sales ratio at 10%, and (3) ROA at 22.5%.

   Needless to say, ABC's management worked diligently to find ways to improve the company's business performance. One strategy was to induce 700 early retirements from the unionized workforce by November 2013. However, as of April 2014, only 480 workers had signed up for this heavily promoted early retirement program that qualified them each to receive a $35,000 cash incentive.

   Besides encouraging workers to retire earlier, what other strategies do you think the ABC Company should pursue to achieve all three of the noted financial targets?

4. The company is considering the introduction of a new product that is expected to reach sales of $10 million in its first full year and $13 million of sales in the second

and third years. Thereafter, annual sales are expected to decline to two-thirds of peak annual sales in the fourth year and one-third of peak sales in the fifth year. No more sales are expected after the fifth year.

The CGS is about 60% of the sales revenues in each year. The GS&A expenses are about 23.5% of the sales revenue. Tax on profits is to be paid at a 40% rate.

A capital investment of $0.5 million is needed to acquire production equipment. No salvage value is expected at the end of its five-year useful life. This investment is to be fully depreciated on a straight-line basis over five years.

In addition, working capital is needed to support the expected sales in an amount equal to 27% of the sales revenue. This working capital investment must be made at the beginning of each year to build up the needed inventory and implement the planned sales program.

Furthermore, during the first year of sales activity, a one-time product introductory expense of $200,000 is incurred. Approximately $1.0 million has already been spent promoting and test marketing the new product.

a. Formulate a multiyear income statement to estimate the cash flows throughout its five-year life cycle.
b. Assuming a 20% discount rate, what is the new product's NPV?
c. Should the company introduce the new product?

5. The New Spirit Corporation has CLs of $130,000 with a current ratio of 2.5:1. Indicate whether the individual transactions specified next increase or decrease the current ratio or the amount of working capital, and by how much in each case. Treat each item separately.
   a. Purchase is made of $10,000 worth of merchandise on account.
   b. The company collects $5000 in accounts receivable.
   c. Repayment is planned of note payable that is due in the current period with $15,000 cash from bank account.
   d. The acquisition of a machine priced at $40,000 is paid for with $10,000 cash, and the lump-sum balance is due in 18 months.
   e. The company conducts a sale of machinery for $10,000. Accumulated depreciation is $50,000, and its original cost is $80,000.
   f. The company pays dividends of $10,000 in cash and $10,000 in stock.
   g. Wages are paid to the extent of $15,000. Of this amount, $3000 had been shown on the balance sheet as accrued (due).
   h. The company borrows $30,000 for one year. Proceeds are used to increase the bank account by $10,000 to pay off accounts due to the supplier ($15,000) and to acquire the right to patents ($5,000).
   i. The company writes down inventories by $7000 and organization expenses by $5000.
   j. The company sells $25,000 worth (cost) of merchandise from stock to customers who pay in 30 days. The company has a gross margin of 40%.
6. The income statement and balance sheet of Superior Technologies are exhibited in Tables 7.20 and 7.21. Conduct a ratio analysis and observe major trends and

TABLE 7.20

Income Statement of Superior Technologies

	Year 2014 (Thousands of Dollars)	Year 2013 (Thousands of Dollars)
Net Sales	193,213	91,954
Cost of goods and services	128,434	60,776
Gross Profit	64,779	31,178
Selling, general, and administrative expenses	26,369	13,844
Employee profit sharing and retirement	9,831	4,167
Total overhead	36,200	18,011
Operating profit before interest and tax	28,579	13,167
Other income	956	273
EBIT	29,535	13,440
Interest paid	680	505
Taxable income	28,855	12,935
Income tax	14,712	6,934
Net Income	14,143	6,001

TABLE 7.21

Balance Sheet of Superior Technologies

	Year 2014 (Thousands of Dollars)	Year 2013 (Thousands of Dollars)
Cash	17,856	10,841
Receivables (net)	29,053	19,350
Inventories	23,282	6,869
Prepaid expenses	664	315
Payments received on government contracts	−6,013	−405
Total CAs	64,842	36,970
Property, plant, and equipment	60,806	26,773
Accumulated depreciation	20,083	10,281
Net property account	40,723	17,492
Patents, etc. (net)	0	249
Other assets	429	80
Total Assets	105,994	53,791
Accounts payable	10,368	5,337
Accrued wages, pensions, taxes, etc.	21,309	10,696
Other CLs	5,589	2,867
Total CLs	37,266	18,900
Long-term debt	29,935	9,250
Preferred stock	3,265	0
Common stock	3,915	3,257
Paid in surplus	8,205	6,228
Retained earnings	23,408	16,156
Total Liabilities and Net Worth	105,994	53,791

deviations from the available historical company information and industry data (see also Table 7.22).

7. For the current fiscal year that starts on January 1, 2015, Buffalo Best Company projects its financial performance as shown in Tables 7.23 and 7.24.

   In fiscal year 2015, the products of the company are priced at $10,000 each. The company president predicts that, because of the generally anticipated recovery of the U.S. economy, there will be a 4% per year increase in each of the next four years (i.e., 2016 to 2019) in (a) price of the company's products and (b) number

TABLE 7.22

Past Ratios of the Company

Past Ratios	Fill in 2014	2013	2012	2011	2010	2009	2008
Current ratio (ratio)		2	2	2.2	2.5	2	1.9
Acid test		1.6	1.2	1.3	1.7	1.3	1
Total debt to total assets (%)		52.3	47.9	41.2	30.4	46	53.3
Long-term debt as percentage of capitalization		26.5	26.3	16.8	8.4	8.3	25.4
Total debt to net worth (ratio)		1.1	0.9	0.7	0.4	0.8	1.1
Days' receivables (days)		75.7	66.3	82.2	96.7	81.9	65.5
Ending inventory turnover (sales)		13.4	7.8	7	7.6	8.1	5.7
Ending inventory turnover (cost of sales)		8.8	5.5	5.1	5.5	5.7	4.1
Net property turnover		5.6	4.4	4.8	4	5.6	6.9
Total assets turnover		1.7	1.8	1.7	1.5	1.6	1.8
Net profit to total assets (%)		11.2	10	8.6	8.1	7.9	8.5
Net profit to net worth (%)		23.4	19.2	14.6	11.6	14.7	18.3
Net profit to net sales (%)		6.5	5.6	5.1	5.5	4.9	4.7
Gross profit		34	29.5	26.5	27.4	29.3	29.2

TABLE 7.23

Income Statement of Buffalo Best

	Year 2014 (Thousands of Dollars)	Year 2013 (Thousands of Dollars)
Sales	18,000	17,000
Cost of goods sold	11,000	10,500
Gross margin	7,000	6,500
Administrative and selling expenses	3,500	3,200
R&D	500	500
Depreciation	1,000	1,000
EBIT	2,000	1,800
Interest	100	100
Taxable income	1,900	1,700
Tax (30%)	570	510
NOPAT	1,330	1,190
Dividends	330	190
Retained earnings	1,000	1,000

TABLE 7.24

Balance Sheet of Buffalo Best

	Year 2014 ($)	Year 2013 ($)
Assets		
Cash and securities	5,000	6,000
Accounts receivable	15000	10,000
Inventory	10,000	7,300
Net fixed assets (investment minus accumulated depreciation)	50,000	51,000
Other	1,000	1,200
Total assets	**81,000**	**75,500**
Liabilities		
Accounts payable	20,000	15000
Other short-term liabilities	26,000	24,000
Long-term liabilities	1,000	1,500
Total liabilities	**47,000**	**40,500**
Equities at par value	1,000	1,000
Capital surplus	12,000	14,000
Retained earnings	21,000	20,000
Total liabilities and owners' equities	**81,000**	**75,500**

of products sold. However, the company's administrative and selling expenses, as well as the product cost per unit, are projected to increase by 7% per year. Other expenses, such as R&D, interests, depreciation, and corporate tax rate, will remain unchanged. The anticipated increase in product cost is primarily due to an increase in materials costs and a decrease in labor productivity because of high turnover rate, poor employee supervision, inadequate workforce compensation policy, cumbersome production processes, and inferior employee training. If nothing is done, the company expects its net income to decrease by as much as 50% around 2018–2019.

At a management meeting on February 12, 2015, the vice president of engineering proposed to hire a consulting firm in the second half of 2015 to develop a customized program for improving labor productivity. She noted that three options are currently available at different investment prices and projected CGS reduction levels:

Program	Investment	CGS Reduction Percentage
A	$700,000	1.0
B	$1,100,000	2.0
C	$1,200,000	3.0

The investment for any one of these options will be a one-time lump sum that can be expensed as an increase in overhead in 2015. The benefits of the consultation program will be realized in a projected reduction of product cost per unit (i.e., the originally anticipated product cost before the management consultation program) by a percentage (1%, 2%, or 3%, respectively) per year for the next four years (i.e., 2016–2019).

The company president welcomes the idea of management consultation as a possible way to enhance workforce productivity. Assuming that the company's cost of money is 10%, he wants to know which management consultation program he should approve.

8. The company's vice president of marketing proposes a new program to significantly increase the product sales by 250,000 units per year throughout the 2016–2022 period. Specifically, it is suggested that the company takes the following actions:
   a. Spend \$2.5 million over the period of 2016–2018 as promotional expenditures—for example, spend \$1.0 million each in the years 2016 and 2017, and \$0.5 million in the year 2018.
   b. Make a one-time investment of \$1.4 million in plants and equipment needed at the beginning of 2016 to generate these additional products. No new warehouse capability is needed. This investment is to be depreciated on a straight-line basis over the seven-year period. There will be no salvage values for these plants and equipment in 2019.

   It is further assumed that the product unit cost is \$8.00 in 2016, and it is estimated to increase by 3% per year. The product unit price is \$20 in 2016, and it is estimated to change as shown in the following table:

Items	2016	2017	2018	2019	2020	2021	2022
Unit price	\$20.00	\$20.60	\$21.00	\$21.15	\$21.25	\$21.25	\$21.00

   The SG&A expenditure is estimated at \$1.25 million in 2016, and it will increase by 3% per year during the six-year period. A corporate tax of 40% must be paid for any marginal income. There is an interest charge during this period, and the company's WACC is 8%.

   If the company's hurdle rate for this type of investment is 25%, would you recommend that the marketing initiative be approved?

9. One of the company's technology patents is about to expire, inducing a likely rush of product entries from the competition. Currently, the product line is projected to have stagnant sales of one million units for the next seven years from 2015 to 2022. The unit price is expected to decrease slightly by 1% per year during the same period.

   The profitability of this product is estimated to be \$1,166,000 in 2015, as indicated in Table 7.25.

   Both the CGS and the SG&A expenses are expected to increase by 3% per year from 2015 to 2022. The depreciation charge is estimated to remain constant at \$1

TABLE 7.25

Simplified Income Statement

	2014 (\$)
Sales	20,000.00
CGS	10,000.00
Depreciation	1,057.00
SG&A	7,000.00
EBIT	1,943.00
Tax at 40%	777.00
EBIAT	1,166.00

million per year, and there is no salvage value for the equipment at the end of 2021. If the product is continued as planned, the company can recover a working capital of \$3.9 million at the end of 2021 from sales of residual inventory and collection of accounts receivable after having discharged all applicable short-term liabilities.

If the management decides to discontinue this product line at the end of 2014, it can sell the fixed assets related to the product line (having a book value of \$7 million) for about \$3 million, and the loss of \$4 million will be tax deductible. Furthermore, the company can recover the working capital (inventory plus accounts receivable, minus accounts payable and other expenses) worth about \$3.9 million at the end of 2014.

Assuming that the appropriate discount rate is 12%, would you recommend that this product line be discontinued at the end of 2014 or continued through 2021?

What is the next-best alternative open to the company, besides either shutting it down immediately at the end of 2014 or continuing to run it till 2021?

10. Define the EVA of XYZ Company, whose income statement and balance sheet are shown in Tables 7.8 and 7.9. Assume that the WACC is 12.35% for both years. Discuss the EVA results and contrast them with the EVA results for Superior Technologies (Tables 7.20 and 7.21), for which WACC is also assumed to be 12.35%.
11. The 2013–2014 income statement and balance sheet for Buffalo Best are presented in Tables 7.23 and 7.24. The WACC for Buffalo Best is 10% for both years. Review and comment on the performance of the company based on the following:
    a. Liquidity, activity, and profitability
    b. Uses and sources of funds
    c. Value creation based on EVA analysis
12. Company X manufactures technology products. It plans to expand its manufacturing operations. Based on past data, management anticipates the first project year of the as-yet-to-be-expanded operations to match the data in Table 7.26.
    a. Compute the working capital requirement during this project year.
    b. Determine the taxable income during this project year.
    c. Calculate the net income during this project year.
    d. Define the net cash flow from this project during the first year.
13. The company has 10,000 shares of common stock outstanding, and the current price of the stock is \$100 per share. The company has no debt. The vice president of engineering discovers an opportunity to invest in a new technology project that yields positive cash flows with a present value of \$210,000. The total initial capital that is required for investing and developing this project is only \$110,000. It is proposed that capital be raised by issuing new equity. All potential purchasers of common stock will be fully aware of the new project's value and cost, and are willing to pay "fair value" for the new shares of the company.
    a. What is the NPV of this project?
    b. How many shares of common stock must be issued, and at what price, to raise the required capital, assuming the costs of underwriting these new shares are negligible?
    c. What is the effect, if any, of this new project on the value of the stock of existing shareholders?

TABLE 7.26

Selected Data of Company X

	($)
Sales	1,500,000
Manufacturing costs	
Direct materials	150,000
Direct labor	200,000
Overhead	100,000
Depreciation	200,000
Operating expenses	150,000
Equipment purchase	400,000
Borrowing to finance equipment	200,000
Increase in inventories	100,000
Decrease in accounts receivable	20,000
Increase in wages payable	30,000
Decrease in notes payable	40,000
Income taxes	272,000
Interest payment on financing	20,000

14. XYZ Company is financed by debt (50%), preferred stocks (20%), and common equity (30%). Its common stock price is $43 per share. It pays a dividend of $3.00 and has a growth rate of –2%. Its annual preferred stock dividend is $82 per $1000 share with a flotation cost of 7.5% per share. The interest for long-term debt is 11%. Its corporate tax rate is 30%.

    What is the company's WACC?

15. ABC Company receives a contract from one of its major customers. The contract calls for 20,000 hours of work billed at $75 per hour to be completed within one year. The normal billable work for each engineer is 2000 hours per year. Thus, the contract requires the involvement of 10 full-time engineers. At the present time, the company has only six full-time engineers who may be able to work on this contract. The engineers' wages average $40 per hour. If the engineers are to work overtime, their overtime pay is time and a half (i.e., $60 per hour).
    a. What would be the contribution margin if 10 engineers were available with no need to work overtime?
    b. What would be the contribution margin if all six engineers were used full time and the deficiency made up through 8000 hours of overtime?
    c. What would be the contribution margin if the company hired two more full-time engineers and made up the rest with overtime?
    d. If the cost of recruiting and training each new engineer is $15,000, what would be the contribution margin on hiring two new engineers, after factoring in recruiting and training costs?

16. New Spirit Company plans to install a new production line consisting of several precision machines costing a total of $800,000. The installation of these machines requires another $150,000. The products made by the machines are projected to deliver a net income after tax of $400,000 per year for the next 10 years. The

useful life of each machine is estimated to be 10 years. At the end of 10 years, these machines have a salvage value of $20,000.

Compute the cash flows generated by this new production line.

17. Using the data contained in Tables 7.20 and 7.21, conduct an evaluation of Superior Technologies' common stock in 2014, using the three different methods specified, as follows:
    a. The market value of the company's net property has risen, and it is now about two times the value reported in the balance sheet. Calculate the stock price by using its *net asset value* as a basis.
    b. Assuming that the company's cost of equity (K_e) is 16%, determine the stock price by applying the *dividend growth model*.
    c. Price to earning (P/E) ratio reflects the general sentiment of the securities market toward a specific company or the industry in general. Assuming that the average P/E ratio is about 10 for the industry, of which the company is a member, define the stock price, using the *earning model*.
18. Company A has been performing reasonably well over the last several years. Table 7.27 shows an abbreviated set of its financial data for the years 2009–2014.
    a. Analyze the company's dividend–payout ratio to common stockholders, and comment on the suitability of this dividend policy.
    b. Discuss the debt financing policy of this company over the years. In your opinion, does the long-term debt of the company represent too high (aggressive) or too low (conservative) a percentage in its capital structure? Why?
    c. Do you regard the percentage of common stock equity in the company's capital structure as adequate, and why?
    d. For 2004, the company needs an influx of $30 million to finance business expansion. Which financing option should the company pursue? Why?
19. Company B is currently financed by common stock equity. It is considering two alternative ways of financing in order to increase the return on common equity. Table 7.28 lists the two options under consideration, along with the base case.

TABLE 7.27

Financial Data of Company A (Millions of Dollars)

	2014	2013	2012	2011	2010	2009
Net income	41	33	34	35	27	22
Preferred dividends	3	3	3	1	0	0
Common dividends	18	18	18	18	13	12
Total assets	492	455	417	403	280	258
CLs	68	57	75	68	51	43
Long-term liabilities	113	114	75	83	57	57
Preferred stock ($100 par)	82	82	82	82	0	0
Common stocks ($6.25 par)	45	45	45	45	38	38
Capital surplus	6	0	0	0	34	34
Retained earnings	177	157	140	126	100	86

TABLE 7.28

Financing Options of Company B

	Base Case ($)	Option A ($)	Option B ($)
Capitalization	30,000,000	30,000,000	30,000,000
Common stock equity	30,000,000	6,000,000	6,000,000
Preferred stock equity	0	24,000,000	0
Long-term debt	0	0	24,000,000
EBIT (operating income)	3,000,000	3,000,000	3,000,000

The company's capitalization and EBIT remain constant at $30 million and $3 million, respectively. The composition of the capitalization changes from 100% common stock equity (base case) to a mix of common and preferred stocks (Option A) and to a mix of common stock and long-term debt (Option B).

The corporate tax rate is 40%. Dividends of preferred stocks are paid at a 5% rate. The interest charge for the long-term debt is 4%.

a. Compute the rate of return on common stock equity for the three cases. Explain why these numbers change from one case to another.
b. Compute the rate of return on capitalization for the three cases.
c. Among the three cases indicated, which financing option is to be preferred by the company, and why?

20. Company X is planning to introduce a new service that is expected to reach sales of $10 million in its first full year and $13 million of sales in the second and third years. Thereafter, annual sales are expected to decline to two-thirds of peak annual sales in the fourth year, and one-third of peak sales in the fifth year. No more sales are expected after the fifth year.

    The CGS is about 60% of the sales revenues in each year. The SG&A expenses are about 23.5% of the sales revenue. Tax on profits is to be paid at a 40% corporate rate.

    A capital investment of one-half of a million dollars is needed to acquire the service delivery equipment. No salvage value is expected at the end of its five-year useful life. This investment is to be fully depreciated on a straight-line basis over five years.

    In addition, working capital is needed to support the expected sales in an amount equal to 27% of the sales revenue of a given year. This working capital investment must be made at the beginning of each year to build up the needed sales support elements to implement the planned sales program.

    Furthermore, during the first year of sales activity, a one-time service introductory expense of $200,000 is incurred. Approximately $1.0 million had already been spent promoting and test marketing the new service before the sales started.

    a. Formulate a multiyear income statement to estimate the cash flows throughout its five-year life cycle.
    b. Assuming a 15% discount rate, what is the new product's NPV?
    c. Should the company introduce the new service?

Appendices

Appendix 7.A: T-Accounts

Accountants use T-accounts as tools to register transactions in preparation for creating financial statements. T-accounts are set up for any items that are assets, liabilities, equities, or other temporary holding entries. A T-account, as displayed in Figure 7.A1, looks like the letter "T." On the left side of the "T," debits are recorded and on the right side, credits are recorded. This type of entry is also known as double-entry bookkeeping.

Following the double-entry bookkeeping practice, every transaction affects at least two entries. This is to ensure that a balance is continuously maintained between both the assets of, and the claims against, the company. Figure 7.A2 illustrates some transactions related to T-accounts.

The company's assets include cash, accounts receivable, inventory, land, machines, plant facilities, marketable securities, and other resources of value. Liabilities include accounts payable, accrued expenses, long-term debts, and other claims creditors have against the company. Owners' equities include stocks, surplus, retained earnings, and other claims of the owners against the company. Equation 7.17 depicts the balance between assets (A) and claims consisting of liabilities (L) and owners' equities (OE):

$$A = L + OE \tag{7.17}$$

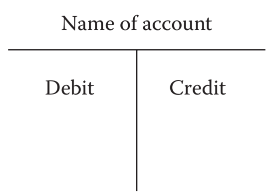
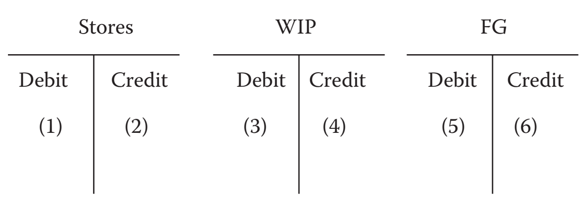


FIGURE 7.A1
T-account.



Explanations:
(1) Purchasing raw materials
(2) Putting materials into production process
(3) Production is initiated, adding value to raw materials.
(4) Production is complete
(5) Receiving of finished goods in storage
(6) Finished goods are shipped for sale

FIGURE 7.A2
Examples of T-account operations.

The convention of T-accounts is: to increase the amount of an asset, debit the account; conversely, to decrease an asset amount, credit the account. All liabilities and owners' equities accounts are treated in the opposite way: that is, to increase a liability or equity amount, credit the account; and to lessen a liability or equity amount, debit the account.

For accounts that do not fall directly into one of these three categories (i.e., A = assets, L = liabilities, and OE = owners' equities), we need to first define their relationships to either A, L, or OE and then treat them accordingly. Revenues, expenses, and dividends are examples of these.

Revenues raise the net income of the company. The resulting net income goes into the retained earnings account for the owners. Thus, an increase of revenues needs to be credited to the owners' equity T-account. The company's expenses are generally deducted from its revenues to arrive at its net income. An increase in expenses results in a reduction of net income and consequently a reduction of owners' equities. Therefore, an increase of expenses needs to be debited to the owners' equity T-account. Similarly, an increase in dividends paid to shareholders whittles down the residual net income amount, which is then added to the retained earnings account of the owners. Thus, an increase of dividends needs to be debited to the owners' equity T-account. Table 7.A1 summarizes the ways in which increases in the indicated assets, liabilities, owners' equities, or other amounts should be treated in their respective T-accounts.

For engineers and engineering managers who are familiar with equations, the rule that follows may represent a convenient way of keeping them better oriented with the T-account convention. Rearranging the basic accounting equation (Equation 7.17), we get

$$\text{LHS} = A - L - OE = 0 \tag{7.18}$$

where LHS stands for the "left-hand side" of the equals sign. Note that for each financial transaction, there are two account entries. The account entry that causes the LHS to increase temporarily should be debited to its respective T-account. Examples include increases in all assets and decreases in all liabilities and owners' equities. The account entry that leads to a temporary reduction of the LHS should be credited to its respective T-account. Equation 7.18 remains valid after both entries of the financial transaction are entered.

TABLE 7.A1

T-Account Convention for an Increase in Selected Account Items

Accounting Items	Debit	Credit
Assets	x	
Cash, accounts receivables, inventory, land machines, marketable securities, and so on		
Liabilities		x
Accounts payables, accrued expenses, long-term debts, and so on		
Owners' equities		x
Stocks, capital surplus, retained earnings		
Revenue		x
Expenses	x	
Dividend	x	

Accountants use T-accounts to collect raw financial data, which they check and recheck for validity and reliability. Then they make sure that the data are relevant to the accounting period at hand and consistent with past practices. Finally, to ensure comparability, accountants regroup them into known line items typically included in financial statements.

Example 7.10

Study the following accounts, which contain several transactions keyed together with letters:

Cash	
(a) 6000	(b) 2500
(e) 1300	(c) 150
	(f) 3500
	(g) 160

Office equipment	
(d) 8500	

Capital	
	(a) 9000

Office supplies	
(c) 150	
(d) 125	

Law library	
(a) 3000	

Legal fees earned	
	(e) 1300

Prepaid rent	
(b) 2500	

Accounts payable	
(f) 3500	(d) 8625

Utilities expenses	
(g) 160	

Explain the nature of each transaction with the dollar amount involved.

Answer 7.10

(a) Convert capital of \$9000, add \$6000 to the cash account, and purchase books worth \$3000 for the Law Library.
(b) Pay the prepaid rent of \$2500 in cash.
(c) Pay office supplies of \$150 in cash.
(d) Purchase office equipment (\$8500) and office supplies (\$125) by credit, creating an account payable of \$8625.
(e) Receive the \$1300 legal fees earned in cash.
(f) Pay accounts payable of \$3500 in cash.
(g) Pay utilities expenses of \$160 in cash.

Appendix 7.B: Financial Risks

In general, the outcome (i.e., earnings) of any investment has a degree of inherent uncertainty: large in some cases and small in others. Investment risk is defined as the measure of potential variability of earning from its expected value. It is usually modeled mathematically by the standard deviation of the outcome when the outcome is expressed in the form of a probability density distribution function (e.g., a Gaussian distribution function; see Section 6.4.3). For common stocks, risk is modeled by a relative volatility index, Beta, as defined in Figure 7.1.

The rate of return on risky security can be modeled as the risk-free rate plus a risk premium:

$$r = R_f + Rp \tag{7.19}$$

The risk-free rate (e.g., R_f equals some constant rate, such as 6.0% for 10-year U.S. Treasury bills) is the return for compensation of opportunity cost without uncertainties. The risk premium Rp is the additional return needed to compensate for the added risks the investors undertake.

Figure 7.A3 illustrates several investment examples and displays the general risk–reward correlation between expected annual return and the associated risk of the investment in question. An investor may realize only 6% from the risk-free U.S. Treasury Bills, but a whopping 25% from highly precarious junk bonds.

1. *Expected value* is the return of an outcome multiplied by its probability of occurrence. For a portfolio containing N independent investments, the total expected return is the sum of the products of individual returns and their respective probabilities of occurrence. The total expected return is the average return weighted by probability factors:

$$\mathrm{EV} = \left[\sum P_i \times R_i; \quad i = 1 \text{ to } N\right] \tag{7.20}$$

where:

R_i = return of investment I

P_i = single-valued probability of occurrence of R_i

$[\sum P_i; i = 1 \text{ to } N] = 1$

2. *Risk aversion* delineates the generally expected unwillingness on the part of investors to assume risks without earning the commensurate benefits. Most investors are unwilling to assume risks unless there are incremental benefits (the risk premium) that compensate them for bearing the added risks involved. Some audacious investors are more willing than others to take on additional risks for the sake of gaining the added benefits.

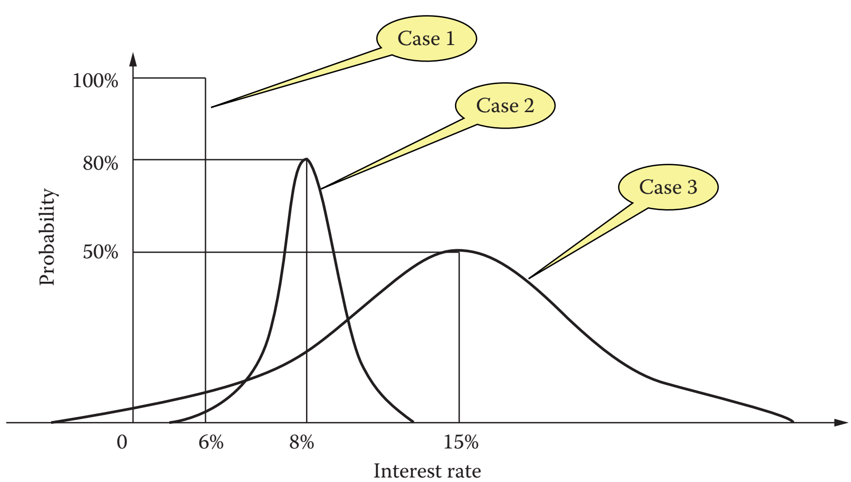


FIGURE 7.A3
Risk curves.

TABLE 7.A2

Behavior of Investors

State of Economy	Investment A (%)	Investment B (%)	Probability
Recession	90	0	0.333
normal	100	100	0.333
Boom	110	200	0.333
Expected payoff value	100	100	—
Range	90–110	0–200	—
Amount at risk	−10	−100	—

Note: Conservative persons would choose Investment A, whereas risk-preferring persons would choose Investment B. Risk-neutral persons would not have a preference.

Table 7.A2 exhibits an example in which the behavior of risk-averse investors can be studied. Investment A has a nominal value of \$100 when the economy is in a normal state. This investment is projected to be valued at \$90 if the economy goes into a recession in the near future. On the other hand, its value may increase to \$110 if the economy booms. Investment B also has a nominal value of \$100 when the economy is normal, but its value decreases to zero in a recession and increases to \$200 in a booming economy.

If we further assume that there is an equal probability of 33.33% that the state of the future economy will be either normal, in recession, or in a booming state, then the expected payoff value of these two investments is identical (e.g., \$100); however, their amounts at risk are different: −\$10 for Investment A and −\$100 for Investment B.

Between these two investment options, a risk-averse investor will choose Investment A for its lower downside risk; he or she will not choose Investment B, because there is no gain in return for the added risks. A risk-preferring investor will choose Investment B for its reward potential of doubling the money if the economy booms in the future.

Appendix 7.C: Derivation of an Infinite Series

Let

$$A = \sum \frac{1}{(1+r)^m} \quad m = 1, 2, \ldots \infty$$

$$B = \sum \frac{1}{(1+r)^{(m+1)}} \quad m = 1, 2, 3, \ldots \infty$$

Then

$$B - A = \frac{1}{(1+r)^{(m+1)}} \tag{7.21}$$

Furthermore, from Equation 7.21,

$$B(1+r)^{(m+1)} - A(1+r)^m = (1+r)^m \tag{7.22}$$

Substituting Equation 7.21 into Equation 7.22, we have

$$A(1+r)^{(m+1)} + 1 - A(1+r)^m = (1+r)^m$$

or

$$A(1+r) + \frac{1}{(1+r)^m} - A = 1$$

$$A = \frac{1 - 1/(1+r)^m}{r} \tag{7.23}$$

As m approaches infinity, we obtain

$$A = \frac{1}{r} \tag{7.24}$$

This relation is used in Equation 7.10.

Appendix 7.D: Derivation of the Dividend Growth Model

$$P_o = \sum_{t=1}^{\infty} \frac{D_t}{(1+r)^t} \tag{7.25}$$

where:

$$D_1 = \text{next year's dividend}$$

$$D_2 = D_1(1+g)$$

$$D_3 = D_2(1+g) = D_1(1+g)^2$$

$$D_4 = D_1(1+g)_3$$

$$\vdots$$

$$P_o = \frac{D_1}{(1+r)} + \frac{D_2}{(1+r)^2} + \frac{D_3}{(1+r)^3} + \cdots$$

$$= \frac{D_1}{1+r}\left[1 + \frac{1+g}{1+r} + \left(\frac{1+g}{1+r}\right)^2 + \left(\frac{1+g}{1+r}\right)^2 + \cdots\right]$$

$$= \frac{D_1}{1+r}\left(\frac{1+r}{r-g}\right) \tag{7.26}$$

$$P_o = \frac{D_1}{r-g} \tag{7.27}$$

where g is the annual increase of dividend, assumed to be a constant fraction of the previous year dividend.

See Equation 7.12.

Appendix 7.E: Derivation of PVGO

The NPV of reinvested retained earnings is

$$\text{NPV} = -(1-b)\,\text{EPS} + (1-b)\,\text{EPS} \times \frac{\text{ROE}}{k_e} \tag{7.28}$$

where the first term on the right-hand side (RHS) of the equals sign is the reinvested retained earnings, with b being the payout ratio. The second term on the RHS describes the capitalized return, assuming the same effective rate as ROE. By substitution, we have

$$\text{PVGO} = \frac{\text{NPV}}{[K_e - g]} = \text{EPS}(1-b)\frac{\text{ROE} - \text{K}_\text{e}}{K_e(K_e - g)} \tag{7.29}$$

See Equation 7.15.

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8

Marketing Management for Engineering Managers

8.1 Introduction

Companies have essentially two major activities: marketing and innovation. Marketing is the whole business of the enterprise seen from the perspectives of customers. The purpose of marketing is to provide products and services that meet the needs and wants of customers. Marketing impacts the top line (i.e., sales revenue) of any enterprise. Innovation strengthens the enterprise's competitive marketing ability to sustain profitability by way of timely application of unique technologies and other core competencies (Kotler 2015; Burrow and Fowler 2015).

In general, science, technology, engineering, and math (STEM) professionals are known to be technologically innovative. If they can also master marketing, the resulting combined capabilities will likely enable them to contribute significantly toward creating business success for their employers and thus propel them to higher leadership positions.

The objective of this chapter is to prepare managers for effective interaction with marketing and sales personnel in companies offering technology-based products and services. Emphasis is given to the introduction and application of marketing concepts for engineering and technology products and services (Tracy 2014; Kerin et al. 2014). The topics that will be discussed include marketing management processes in profit-seeking organizations, identification of opportunities and threats facing an organization, and key strategies in the marketing of products and services.

STEM professionals are encouraged to continue studying additional current references on specific issues in marketing management.

8.2 Function of Marketing

Marketing and sales personnel are critically important to profit-seeking companies because they strive to ensure satisfaction in the exchange of values between the producers and consumers of products and services, as exhibited in Figure 8.1.

8.2.1 Sales versus Marketing

Sales is a process by which producers attempt to motivate target customers to buy the available products. The mentality behind sales, as illustrated in Figure 8.2, is that "someone out

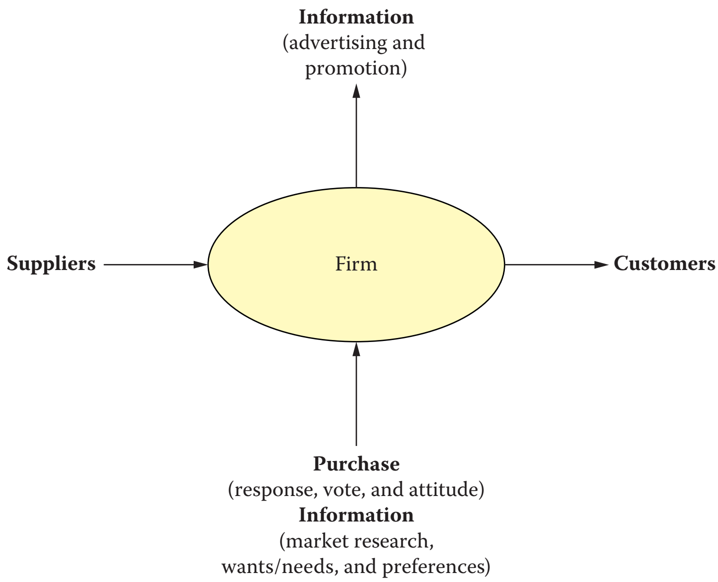

FIGURE 8.1
Exchange of values.

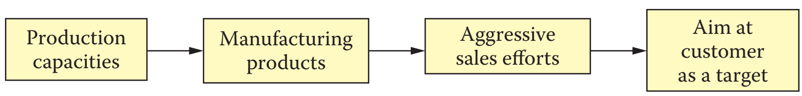

FIGURE 8.2
Sales mentality.

there will need the products." At the time when Ford Motor Company was the dominant carmaker in Detroit, the well-known saying attributed to Henry Ford was, "You can have any color you want for your car, as long as it is black." Sales does not take the customers' concerns into account.

In contrast, companies with a marketing orientation offer something that customers want by seeking feedback from the marketplace, adjusting the product offerings, and increasing the product's value to consumers (see Figure 8.3).

In the pursuit of marketing strategies, companies solicit intelligence, financial data, and customers' responses to constantly reassess the market. They evaluate such factors as product reliability, safety, competition, cost-effectiveness, product substitution, and maturity of products. A long-term orientation ensures that benefits for both producers and customers will be sustained. Sales strategies are only a part of marketing (O'Keefe 2013; Dannenberg and Zupancic 2014).

8.2.2 Marketing Process

The marketing efforts of companies are typically centered on four specific dimensions (McDonald and Wilson 2011):

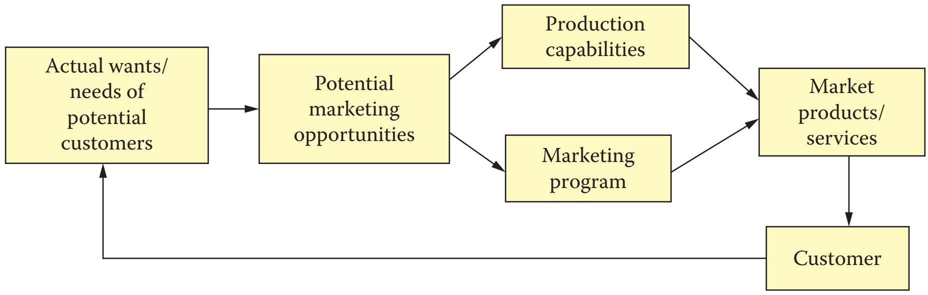

FIGURE 8.3
Marketing mentality.

1. *Customer focus*: The purpose of a profit-seeking business is to understand customers' needs, deliver value to customers, and offer services to ensure that customers are satisfied. In other words, the customer comes first. All product designers must pay more heed to customers.
2. *Competitor orientation*: Companies seek advantages relative to their competitors, monitor their behaviors, and respond to their strategic moves.
3. *Interfunctional coordination*: Companies integrate all functions, share information, and organize themselves to provide added value to the customers.
4. *Profit orientation*: Companies attempt to make profits in both the short term and the long term.

To achieve business success, companies must search constantly for future markets, in addition to actively serving today's markets. The primary responsibility of the marketing department is to scan the relevant business environment for future opportunities (such as what bundle of products and services to offer to whom, at what price, at what time, and in which market segments) and to provide insight into the needs of current customers and the intentions of competitors.

Presented in Figure 8.4 is the marketing process, which is iterative in nature. This process defines opportunities (unsatisfied needs) in the marketplace; the features of products

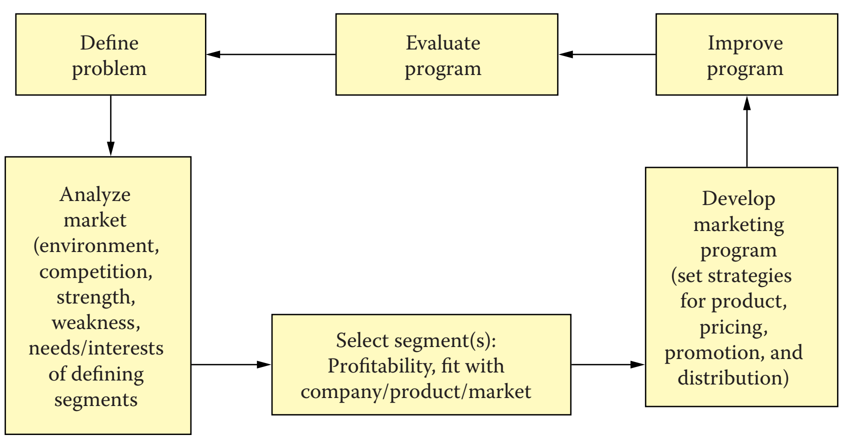

FIGURE 8.4
Marketing process.

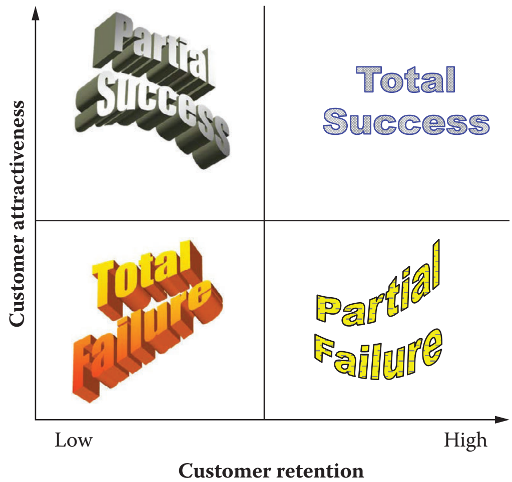

FIGURE 8.5
Marketing effectiveness diagram.

or services to satisfy these needs; and the pricing, promotion, distribution, physical evidence, process design, and people strategies to reach the target market segments under consideration. Market segments refer to specific groups of customers who share similar purchasing preferences, as identified by the company to sell products/services to.

For companies to succeed in the marketplace, marketing must be a core activity central to the company's strategy formulation and execution. Through marketing, companies identify and satisfy the needs of customers and achieve long-term profitability by attracting and retaining customers. Specific tasks undertaken to attain these objectives include (1) interacting with and understanding the market and its customers, (2) planning long-term marketing strategies, and (3) implementing short-term tactical marketing programs.

The effectiveness of a marketing program is often measured by two metrics: (1) how attractive the company's products and services are to the target customers and (2) how successfully the company can satisfy and retain these target customers. Figure 8.5 illustrates the marketing effectiveness diagram.

The marketing program of a company is regarded as a *total success* if both customer retention and product attractiveness to customers are high. This is when high profitability can be achieved at a maximum growth rate. The marketing program scores a *partial success* if the product attractiveness to the customer is high, but the customer retention is low. While lost customers are typically replaced by new customers, the total customer base will show little growth. *Partial failure* is assigned to a marketing program when product attractiveness to the customer is low, but the customer retention is high. Under this scenario, business remains stagnant because it relies on loyal customers to repeatedly buy mature, noncompetitive products. The company's sales may slow down or fall as few new customers are added. The marketing program is a *total failure* if both product attractiveness to the customer and the customer retention level are low. Customers are leaving, and the company's sales are falling.

Marketing strategies are implemented at the corporate, business, and operational levels. Top management provides inputs toward identifying future opportunities, and addresses questions such as what business the company is in and what business the company should be in. The business managers then devise the proper marketing plan to bring out products or services, and strive to create and maintain a sustainable competitive advantage in the marketplace. At the operational level, managers and support personnel conduct planning for specific marketing programs, and implement and control marketing efforts related to segmentation, product design, pricing, distribution channels, and communications.

8.2.3 Key Elements in Marketing

Those who plan and implement marketing programs are called *marketers*. Marketers consider various influence factors and make diverse decisions to penetrate a specific marketplace (Taderera 2010). Marketers pay attention to several key elements of marketing, such as the market itself, the environment, the customer, the product, pricing, promotion, and distribution.

The *market* is made up of buyers who are expected to purchase certain products and services, and also buy substitutes that offer similar values. Of great importance to the marketers is the size of the expected market, measured in millions of dollars per year, its growth rate, its geographical characteristics, and its requirements. The market must be large, stable enough with a reasonable growth rate, and relatively easy to reach and serve in order for it to be a worthwhile target for the marketers.

The *environment* refers to competitors, barriers to entry, rules and regulations, resources, and other such factors affecting the marketers' success in a given market segment. Marketers must also understand the opportunities and threats present in the environment.

The *customers* consist of all potential buyers of a given product or service. Companies need to understand why they buy, how they buy, who makes the decision to buy, who will use the product, in what specific way the use of the product will contribute value to the user, what might be the buyer's preference related to service and warranty, what other product features the customer may want, and other factors. The more a company knows about its customers, the better the company can serve the customers in order to build and maintain competitive advantages in the marketplace. (Appendix 8.B contains additional sample customer survey questions.)

To become customer-oriented, companies need to (1) define the generic needs of customers through research (such as the buyer's perception of an automobile's status, safety, or cost), (2) identify the target customers by segmentation (including which selected groups of customers have shared needs), (3) differentiate products and communications (e.g., offering special reasons for customers to buy due to unique product attributes or special communications), and (4) bring about differentiated values for customers.

The *product* or *service* symbolizes the actual "bundle of benefits" that is offered to customers by the marketers. Factors considered include functional attributes, appropriateness to customer needs, differentiable features over competition, product line strategy (e.g., synergy between products/services offered; e.g., Apple Watch products are intentionally tied into iPhones to form a unique ecosystem), and product-to-market fit (e.g., Apple products are generally favored by music-loving young adults).

Promotion and *communication* consider the advertising strategies of product and brand promotion, options to use a push–pull strategy, selection of advertising media, and the choice of promotional intensity. These ensure that the selected means of communication are compatible with the target market segments.

The *pricing strategy* concerns itself with the choice of either a skimming or a penetrating strategy to set the price, the use of value-added pricing, and the fit of a chosen pricing strategy to the target segment.

The *placement (distribution) strategy* defines options such as the product delivery options of either an intensive, exclusive, or selective distribution system; the company's relationship with dealers; and the changes in distribution systems.

The *physical evidence* refers to the physical setting (e.g., a store's appearance, layout and color; the dress of service staff; service equipment; and service brochures) that affect customer experience.

The *process design* specifies the applicable operations policies and procedures to effectively serve the customers as related to order processing, logistics, inventory planning, franchising policies, sales training, and flow of activities in delivering services.

The *people* refers to customer-facing service staff, whose training, attitude, and behavior directly affect the customer experience.

The first four marketing elements are emphasized when marketing products. For marketing services, the last three elements are added. These elements characterize the multidimensional nature of marketing and are centered on customers, who are the focus of any successful marketing program.

8.2.4 Marketing Mix

There are a total of seven key elements of marketing that form the *marketing mix* (Francese 1996) (see Figure 8.6). Specifically, the marketing mix consists of price, promotion, product, placement (distribution), physical evidence, process designs, and people—the seven *P*'s of marketing.

To help the reader understand the market and the customer, market forecast and market segmentation are introduced in Sections 8.3 and 8.4. The first four marketing mix elements are addressed in detail in Sections 8.5 through 8.8. Sections 8.9 through 8.11 discuss the remaining three marketing elements of physical evidence, process design, and people.

Example 8.1

A company has divided the market for its existing products into three segments: mass-market applications; applications requiring a quality product, even though consumers continue buying on price; and critical applications, in which both quality and reliability

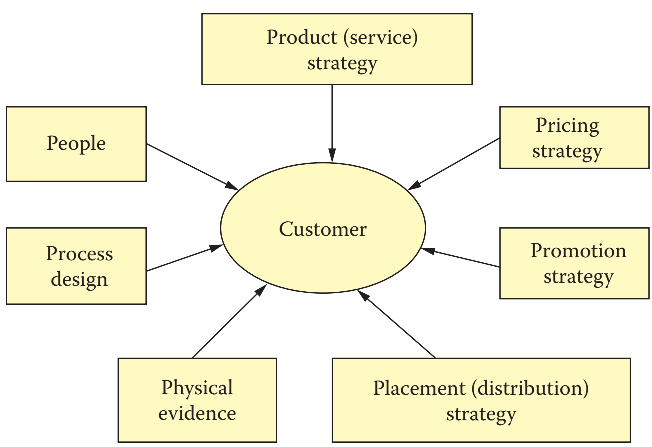

FIGURE 8.6
Marketing mix.

TABLE 8.1

Marketing Strategies for Specific Segments

	Segment 1	Segment 2	Segment 3
Price	Low	Low	High
Product/service	Standard	Quality	Quality and reliability
Promotion	Broad	Limited	Focused
Place	Multiple distributions	Multiple distributions	Direct
Physical evidence	Not important	Low emphasis	High emphasis
Process	Highly efficient	Efficient	Standard
People	Standard	Standard	Dedicated

are important. Advise the company on the marketing mix that should be applied to these three segments.

Answer 8.1

For the company to be successful, a different set of marketing strategies needs to be applied to each of these segments, as suggested in Table 8.1.

Multiple distributions are recommended, including mass-merchandise department stores for wide distribution. Direct distribution should include catalogs, specialty stores, and upscale department stores.

8.3 Market Forecast: Four-Step Process

The purpose of conducting a market forecast is to define the characteristics of the target market regarding its potential size, stability, growth rate, and serviceability. The market size and growth rate must be large enough to warrant further consideration by marketers (Hyndman and Athanasopoulos 2013; Chase 2013).

Any future market is always uncertain due to potential changes in end user behavior, global economics, new technologies, competition, and economic and political conditions.

Barnett (1988) emphasizes that the key to successfully forecasting market size is to understand the underlying forces behind the demand. Barnett proposes the following four-step process: (1) define the market, (2) segment the market, (3) determine the segment drivers and model its changes, and (4) conduct a sensitivity analysis. These steps are explained next.

On the basis of customer interviews, the market should be defined broadly to include the principal product to be marketed, its "bundle of benefits" to customers, and the competitive products that customers could buy as substitutes instead.

In segmentation, the potential customers for the principal product/service are divided into homogeneous subgroups (segments) whose members have similar product preferences and buying behavior.

Segment drivers are the key factors that drive the growth of a specific segment. Segment drivers may be composed of macroeconomic factors (e.g., the increase in white-collar workers and in population), as well as industry-specific factors (e.g., the industrial growth rate and business climate). Possible sources of information related to segment drivers are industrial associations, governments, industrial experts, marketing data and service providers, and specialized market studies.

Sensitivity analyses are conducted to test assumptions. Monte Carlo simulations may be performed to generate the maximum—most likely—and minimum total market demand sizes, as well as an assessment of the risks involved (see Section 6.4).

The following are two illustrative examples in which the total market demand for a product is estimated by (1) defining the industrial segments that purchased the product in the past, (2) determining the future growth rates of these industrial segments, and (3) calculating the total market demand for the product with these industrial segment growth rates as the segment drivers. The assumption here is that the product demand of a given industrial segment is in direct proportion to its segment growth rate.

For example, to predict the demand of electricity in future years, a utility company has subdivided its consumers into three segments: industrial, commercial, and residential. The need for electricity by the industrial segment depends on its future production level and business climate. The electricity demand by the commercial segment is related to retail sales that in turn are negatively affected by retail stores consolidating, and by growing online sales. The residential electricity demand is affected positively by new home sales and home sizes, and negatively by the increased energy efficiency of home appliances.

A second example is a paper-producing company that needs to determine the total market demand for uncoated white paper. The company divides the market into end-use segments such as business forms, commercial printing, reprographics, envelopes, stationery, tablets, and books. The drivers in each segment are then modeled in terms of macroeconomic and industrial factors, using regression analysis and statistics. Examples of applicable drivers include growth in the use of electronic technology, white-collar workers, the present level of economic activity, the growing use of personal printers, population growth, demand growth induced by price reduction, and the practice of paying bills online.

Market forecast is a difficult, but critical first step to take when developing a marketing program. Companies routinely engage both internal and external resources to assess the principal characteristics of the target markets for their products.

8.4 Market Segmentation

Once it is determined that the target market is worth pursuing (i.e., the market is large and stable enough with a high growth rate), then it is useful to understand the target customers so that they can be served well. Market segmentation is a process whereby companies recognize the differences between various customer groups and identify the representative group behaviors. Generally speaking, members in each of these customer groups do respond to product or service offerings in similar ways and have comparable preferences with respect to the price–quality ratio, reliability, and service requirements (Bodea 2014).

By dividing consumers into groups that have similar preferences and behaviors with respect to the products being marketed, companies achieve four specific objectives: (1) matching products and services to appropriate customer groups, (2) creating suitable channels of advertisement and distribution to reach these customer groups, (3) uncovering new customer groups that may not have been served sufficiently, and (4) focusing on niches that have been neglected by competitors.

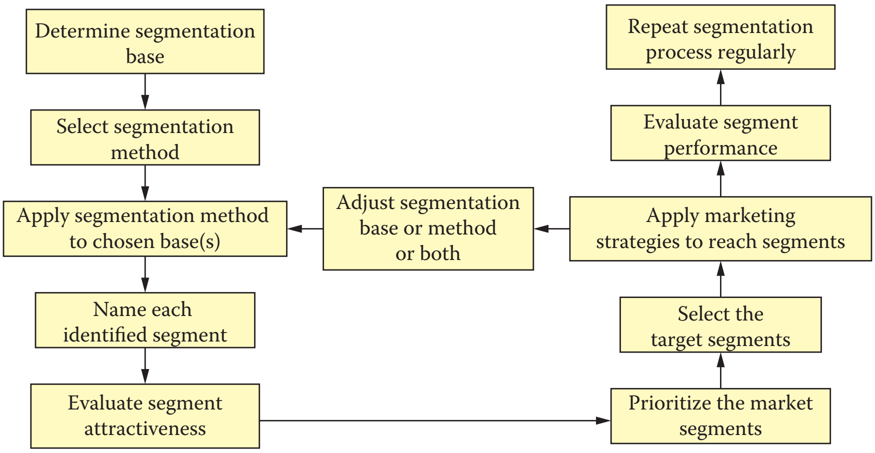

FIGURE 8.7
Segmentation flow diagram.

In addition, segmentation allows companies to realize the following benefits: developing applicable marketing strategies and objectives, formulating and implementing marketing programs that address the needs of the different customer groups, tracking changes in buying behavior over time, understanding the enterprise's competitive position in the marketplace, recognizing opportunities and threats, and utilizing marketing resources effectively. Figure 8.7 shows a segmentation flow diagram that illustrates the key steps in segmenting a market.

Companies classify consumers into segments by understanding their individual, institutional, and product-related characteristics. *Individual* characteristics include culture, demographics, location, socioeconomic factors, lifestyles, family life cycle, and personalities. *Institutional* characteristics include the type of business, its size, and the extent of its global reach. *Product-related* characteristics include type of use (e.g., original equipment manufacturer [OEM] versus end user), usage level, product knowledge, brand preference, and brand loyalty. The benefits sought by consumers—such as psychological and emotional benefits, functional performance, and price—should also be analyzed.

Millions of consumers purchase cars every year. To some, cars are a status symbol; to others, cars are simply a means of transportation. A large number of car buyers emphasize safety and reliability, while others focus on styling or fuel economy. Socioeconomic factors, demographics, personalities, and family life are all known to influence the behavior of car buyers. These consumers are extensively segmented by all major carmakers.

To be effective, the segmentation of a market needs to satisfy several requirements. The segmentation should be measurable. It should result in readily identifiable customer groups. The identified customer groups should also be homogeneous. Each group's members should possess more or less unified value perceptions and display compatible behavioral patterns. These customer groups are reachable by means of promotion and distribution. Above all, the segments should be large enough in size to justify marketing efforts, and they should have a high growth rate to allow the company to achieve long-term profitability.

There are pitfalls to market segmentation. Certain "old economy" companies adopt the asset-rich business strategy of pursuing the scale of economy advantages. For these companies, a potential pitfall is over-segmentation, because the selected segments may be too small or fragmented to serve effectually. Such an over-segmentation is not a pitfall for other "knowledge economy" companies that form partnerships to establish supply chains for "build-to-order" products. To foster differentiation, knowledge economy companies pursue product customization as the basis for their business strategies (Struhl 2013). Examples of these products and services are minibrewers, computers, and custom cosmetics. For other companies, overconcentration (lack of balance between segments) could have a negative impact on their overall marketing effectiveness (Hartley and Claycomb 2013).

Market segmentation is a prerequisite to developing a workable marketing program. Knowledge derived from customer groups serves as valuable inputs to product design, pricing, advertising, and customer services, all of which need to be carefully defined by the company.

8.5 Product/Service Strategy

The product/service strategy takes center stage in any marketing program (Haines 2014). If marketed properly, products/services that offer unique and valuable functional features to consumers are expected to enjoy a strong marketplace acceptance.

Products/services may be generally classified as either industrial or consumer oriented. Their characteristics are different, as shown in Table 8.2. Marketing programs for consumer products are quite different from those for industrial products, even though the same basic marketing approach applies to both (Ulrich and Eppinger 2011).

A good marketing program must take into account the consumer's perception regarding products/services. Indeed, consumers perceive products/services in different ways than the producers and marketers do. When buying products/services, consumers look for

TABLE 8.2

Industrial and Consumer Products

	Industrial Products/Services	Consumer Products/Services
1. Number of buyers	Few	Many
2. Target end users	Employers	Individual
3. Nature of products/services	Tailor-made, technical	Commodity, nontechnical
4. Buyer sophistication	High	Low
5. Buying factors	Technical, quality, price, delivery, service	Price, convenience, packaging, brand
6. Consumption	OEM parts for reselling, own consumption	Direct consumption
7. Producer end-user contact	Low	High
8. Time lag between demand and supply	Large	Small
9. Segmentation techniques	SIC (standard industrial classification), size, geography, end user, decision level	Demographics, lifestyle, geography, ethnic, religious, neighborhood, behavior
10. Classification of goods	Raw materials, fabricated parts, capital goods, accessory equipment, MRO supplies	Convenience (household supplies, foods), shopping (cameras, refrigerators), specialty (foods, brand-name clothing)

TABLE 8.3

Examples of Customer's Perspectives

Services	Vendor's Perceptions	Consumers Perceptions
Major surgeries	Sequences of diagnostic tests Surgical procedure Medications, emergency steps	Hope of recovering while enduring pain and suffering
Financial advisement	Models, diversification strategy Economic projections Projected risks in global economy	Chances of preserving capital and making money

"bundles of benefits" that satisfy their immediate wants. Products/services that producers regard to be different because of physical embodiment (e.g., input materials), production process, or functional characteristics may in fact be equivalent from the customers' perspectives, if offering the same or similar benefits. Table 8.3 contains illustrative examples of these different perceptions. Companies must define competition based on the way customers perceive their products. Note that products that appear to be physically different to marketers may appear to be the same to users.

A product/service strategy must also be established with respect to competition. A company may decide to market premium products, characterized by having features that are outstanding or superior to those offered by the competition. Such outstanding product/service features may be possible because of the company's innovative capabilities, technological superiority, and other core competencies. Companies with such "high-road" brands (see Section 8.5.5) tend to enjoy and sustain high profitability. Other companies may elect to make commodity-type (value) products with commonly available features so that they compete head-on against their competitors on the basis of price, service, distribution, and customer relations management. They pursue the option of "low-road" products. Product positioning is the step that addresses such competitive issues.

8.5.1 Product/Service Positioning

An important question that companies should ask is, which product/service attributes should be included? A *perceptual map* is a useful tool to position the company's products/services in relation to existing competitive offerings in the marketplace. It enables companies to select the correct set of product/service attributes to maximize its marketing advantages. It also articulates customer preferences and identifies gaps; these are useful steps in positioning new entries or repositioning existing products (Czerniawski and Maloney 2010).

Figure 8.8 is an example of a perceptual map for automobiles regarding the product attributes of price and styling. Only the relative magnitudes of the attributes are emphasized in such a map. However, the map helps to identify which car models are in direct competition with one another and which ones are not. It is also possible to link customer segments to these pairs of product attributes, thus enabling companies to refine their advertising strategies for these customer segments.

Products/services with more than two important attributes are readily mapped into an n-dimensional perceptual map. A product (e.g., P_1) is designated by a single point having the coordinates F_1, F_2, F_3, through F_n, with each representing an independent product attribute. This representation is complete if the elements of the attributes set ($F_1, F_2, \ldots, F_n$) are mutually exclusive and collectively exhaustive. For example, for automobiles, these

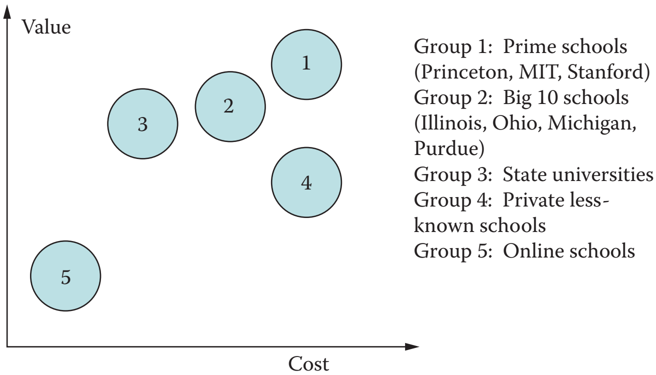

FIGURE 8.8
Example perceptual map for automobiles.

attributes may include price, styling, fuel economy, driving comfort, safety, brand prestige, power, and longer-term dependability (e.g., number of problems per 100 three-year-old vehicles). The spacing between two neighboring points (each identifying a product) as depicted in this *n*-dimensional map is equal to the square root of the sum of the individual attribute differences, squared. Figure 8.9 presents an example of the description of products with six distinguishable attributes.

8.5.2 Product/Service Life Cycles

Every product/service goes through a number of important stages throughout its useful life (Stark 2011; Acevedo 2014). These stages include:

1. The *initiation stage*—product testing, market development, and advertising
2. The *growth stage*—product promotion, market acceptance, and profit growth
3. The *stagnation stage*—price competition, substitution, and new technologies
4. The *decline stage*—cash-cow strategy with no more investment.

Product/Service/Features	*F*1	*F*2	*F*3	*F*4	*F*5	*F*6
S1						
S2						
S3						
S4						
Your product/service						
S5						
S6						
S7						

FIGURE 8.9
Competitive positioning for products with six distinguishable attributes.

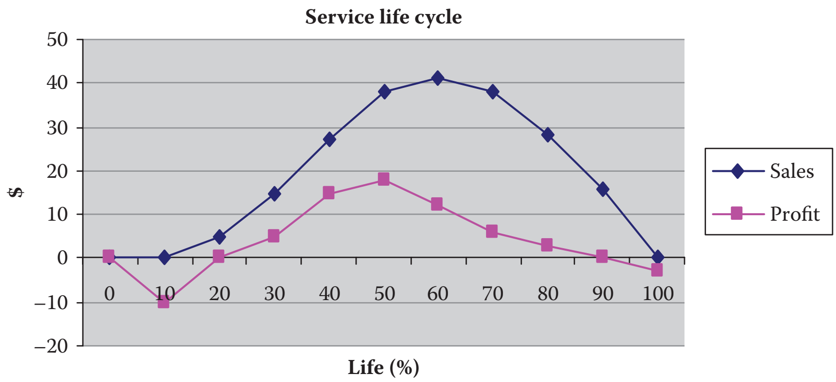

FIGURE 8.10
Life cycle.

Companies need to understand which phase a given product is in (see Figure 8.10).

From the standpoint of the product life cycle, an important product strategy is to sequence the introduction of new products so that a high average level of profitability can be maintained for the company over time.

Engineering managers are particularly qualified to constantly come up with innovative products so that their employers may introduce these products at the right intervals.

8.5.3 Product Portfolio

Another product strategy issue is related to the types of products concurrently being marketed. With the exception of a few, most companies market a group of products at the same time, referred to as a *product portfolio* (Thakor 2012).

Products in a portfolio are usually not "created equal." From the company's standpoints of profitability and market share position, some are more valuable than others. Boston Consulting Group (BCG) of Boston, Massachusetts, developed a portfolio matrix based on two measures, namely, growth rate and market share (see Figure 8.11). According to this classification scheme, products are regarded as *stars* if they enjoy high growth rate and

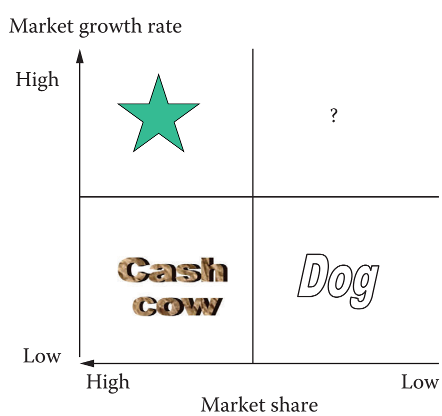

FIGURE 8.11
Classification of products/services.

high market share and *question marks* if they have high growth rate, but low market share. *Cash cows* are those products with low growth rate and high market share. Products are designated as *dogs* if both growth rate and market share are low.

Figure 8.11 indicates that companies need to differentiate the products/services they market by strategically emphasizing some and de-emphasizing others, according to the responses from the marketplace. For example, a useful strategy to manage a product portfolio is to milk the *cash cows* for capital to build *question marks* into *stars* that will eventually become *cash cows*. Divest the *dogs*.

8.5.4 Company Brands

Numerous HT companies operate in a "product-centric" business model, in that they market products on price and performance. Recent market studies show that the success of technology-based products/services in the marketplace is not purely dependent on the price–performance ratio, but also on the trust, reliability, and promised values the customers perceive in a given brand.

According to Yohn (2014), brand is "a distinct identity that differentiates a relevant, enduring and credible promise of value associated with a product, service, or organization that indicates the source of that promise." The brand of a company is more than a name. It stands for all the images and experience (e.g., products, service, interactions, and relations) that customers associate with the organization. It is a link forged between the company and the customers. It is a bridge for the company to strengthen relationships with customers, according to Wheeler (2012).

A promise of value is an expectation of the customer that the company is committed to deliver. Examples of such promises of value from several companies are listed in Table 8.4. They must be relevant to the enduring needs of the targeted customers and made credible by the persistent commitments of the company. To be competitive, the promise of value must be distinguishable from those offered by other brands.

Research indicates that customers consider questions at five levels when purchasing both HT and consumer types of products. These questions may be grouped into a brand pyramid, as illustrated in Figure 8.12.

Technology-oriented buyers are typically focused on questions at Levels 1 and 2. However, higher-level business managers who make purchase decisions are also known to address questions at Levels 3–5. These decision-makers are interested in what the product or service will do for them, not just how it works. Consequently, to project a trustworthy and reliable image, to build strong relationships with customers, and to enhance brand loyalty and customer retention, companies are well advised to pay attention to questions at all five levels. This is the emphasis of brand management.

Brand is evaluated on how well it is doing with respect to a number of metrics: delivering according to the customer's desire, relevance to the customers, value to the customers,

TABLE 8.4

Examples of Promise of Value

Corporate Brands	Promises of Value
IBM	Superior service and support
Apple	Simple and easy to use
Lucent	Newest technologies
Gateway	Friendly service

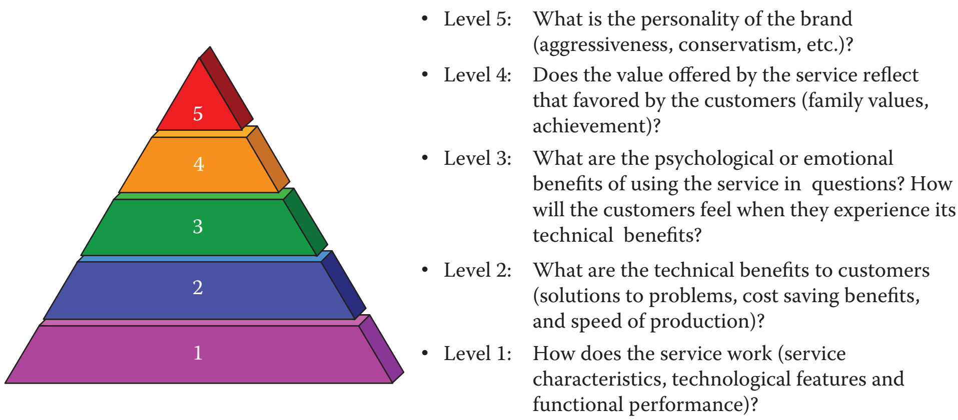

FIGURE 8.12
Brand pyramid.

positioning, product portfolio management, and integration of marketing efforts, management, support, and monitoring. Brand is a major asset that must be properly managed and constantly strengthened. Useful inputs for brand management are typically secured from customer feedback. Once the market is properly segmented, the promise of values is specifically designed to address the needs of the target segments involved. Actions are then taken to deliver the stated promise of values, and results are constantly measured to monitor progress.

In the past, brand management has been focused primarily on points of difference, such as how a given brand differs from the other competing brands within the same category. Maytag is known to emphasize "dependability." Tide focuses on "whitening power." Recently, Keller et al. (2002) suggested that attention should be paid to points of parity and the applicable frame of reference, in addition to the points of difference, when marketing a given brand. Emphasizing the frame of reference is intended to help customers recognize the brand category comprising all of the competing brands. Focusing on the points of parity will ensure that customers recognize a given brand as a member of the identified brand category.

Brand may be classified with respect to the two dimensions, namely, category and relative market share. The brand category is defined as *premium* if the category is dominated by premium brands—those with high values to customers. Examples of premium car brands include BMW, Mercedes-Benz, Jaguar, and other luxury and specialty cars that each have unique high-value attributes. The brand category is defined as *value* if it is dominated by value brands—those with basic, minimum, low-end attributes. Examples of value car brands include Chevy, Saturn, and other compact and four-door family cars. Gillette markets its Mach-3 Turbo shaving system as a premium brand, whereas the cheap disposable razors from its own company as well as its competitors, are marketed as the value brands. The relative market share refers to the percentage of market share a given brand is able to attain.

In Figure 8.13, brands are grouped into four classes: high-road, low-road, hitchhiker, and dead-end brands (Vishwanath and Mark 1997). Return on sales (ROS) is defined as net income divided by the sales revenue (see Section 7.4.1).

High-road brands are those with products that offer premium features, options, qualities, and functions to command high selling prices while attaining a leadership position in the market share. Examples of such high-road brands are Coca-Cola, Frito-Lay, and Nabisco. These brands enjoy excellent profitability that may be sustained for long periods. The key success factors for high-road brands are technological innovation (constantly

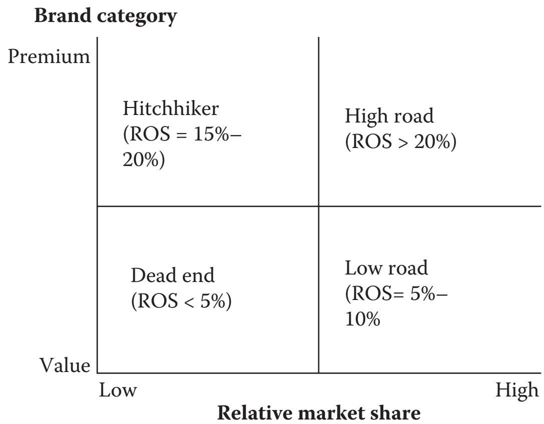

FIGURE 8.13
Brand classes.

adding new product/service features and values), time to market, flexible manufacturing, and advertising.

Low-road brands are those that offer value brands while enjoying a high market share position. Because of marketplace competition and a lack of distinguishable product features, these brands can be successfully managed by emphasizing cost reduction, production efficiency, product simplification, and distribution effectiveness.

Hitchhiker brands are those with premium product values and low market share. For these brands to become high-road brands, management must emphasize cost reduction, flexible manufacturing, and product innovation.

Dead-end brands are value brands with low market share. These brands attain only marginal profitability. There are several strategies to grow the profitability of these dead-end brands: (1) reduce the price to penetrate the market and thus move these brands to the low-road category; (2) increase the scale of economies by applying the "string-of-pearls" strategy: producing and marketing several products together to cut costs; (3) introduce a superior, premium product to "trump" this brand into the hitchhiker category. Failing all of these attempts, dead-end brands should be discontinued. Table 8.5 summarizes the strategies that deal with these four classes of brands.

The preceding discussion on product brands should assist engineering managers in understanding the significant value added by brands to the success of the company's marketing program (Keller 2012). Such an understanding would make it easier for them to channel their support efforts to actively enhance the company's brand strategy.

8.5.5 Engineering Contributions to Product and Brand Strategy

The product/service is a key element in the marketing mix. STEM professionals have major opportunities to add value by (1) understanding the customers' perceptions of products; (2) designing products/services with features that are wanted by customers; (3) helping to position the company's products/services strategically to derive marketing advantage; (4) practicing innovations in the design, development, production, reliability, serviceability, and maintenance of product/services to differentiate them from others;

TABLE 8.5

Strategies for Four Different Brands

Brands	Strategic Options
High road	Apply R&D to constantly innovate to make services premium—adding new service features and changing forms and functions
	Expand service lines (service proliferation)
	Initiate media campaign
	Capital investment
	Decrease time to market
	Flexible manufacturing
	Direct store delivery to preoccupy shelf space
Low road	Pursue cost reduction aggressively
	Lessen service proliferation (SKUs) by simplifying service types and designs
	Consolidate production facilities to improve efficiency and cut wastes
	Use realized cost savings to slash price
	Consider ways to add premium services (advancing to high road)
Hitchhiker	Apply R&D to constantly innovate to make services premium—adding new service features and changing forms and functions
	Cost reduction
	Reduce time to market
	Flexible manufacturing
	Initiate media campaign
	Consider capital investment
Dead end	Cut price (advancing to low road)
	Outsource in areas with economies of scale
	Apply the "string-of-pearls" strategy to enhance scale
	"Trump" the category by introducing a superior, premium service that resets consumer's expectation (advancing to hitchhiker)
	Do not spend on marketing
	Make no capital investment

Source: Vishwanath, V. and Mark, J. *Harvard Business* Review, May–June 1997.

(5) sustaining the company's long-term profitability by creating a constant flow of new products/services for introduction on a timely basis; (6) assisting in managing companies' product/service portfolios by adding premium features to some and reducing costs to others; and (7) ensuring commercial success of the high-road and hitchhiker brands in the marketplace.

In the "knowledge economy" of the twenty-first century, time to market is an increasingly important competitive factor. Once the desirable set of product/service attributes is known from market research, those companies that bring the suitable products to the market first will enjoy preemptive selling advantages and will recover their product development costs faster than others. Engineering managers should also be well prepared to contribute in shortening the products' time to market by utilizing advanced technologies to create modular design, eliminate prototyping, whittle away design changes, foster parts interchangeability, ensure quality control, and other innovations.

8.6 Pricing Strategy

Price is a very important product/service attribute (Jensen 2013; Nagle et al. 2010). Companies pay a great deal of attention to the setting of product prices. Setting the price too high will discourage consumers from buying, whereas setting it too low will not ensure profitability for the company. Generally speaking, the two major strategies for setting the product prices are the skimming strategy and the penetrating strategy.

8.6.1 Skimming and Penetration Strategies

Companies applying the *skimming strategy* set the product price at the premium levels initially and then cut the product price in time to reach additional customers. In other words, they "skim the cream" first. An example is the marketing of a new book with hardcover copies selling at a high price (e.g., $29.95) followed by the paperback version at a low price ($4.95). New technology products are also typically sold at high prices initially in the absence of competition. As competitors enter the market with products of similar features, product prices are lowered accordingly.

In contrast, companies pursuing the *penetration strategy* set product prices low to penetrate a new market and rapidly acquire a large market share. A high market share position sets forth a barrier of entry for other potential competitors. In general, companies use a penetration pricing strategy to enter an existing, but highly competitive market. An example is the marketing of Japanese motorcycles in the United States.

8.6.2 Factors Affecting Price

In setting product prices, besides using the skimming and penetration strategies, companies broadly consider a number of other factors: financial aspects, product characteristics, marketplace characteristics, distribution and production capabilities, price–quality relationship, and the relative position of power (Hamilton 2014). These factors will be discussed next.

Financial aspects: The more solid the company's financial position, the more capable it is at initially setting the product price low. Companies strong in finance stay afloat for a long period of time even with low profitability. Companies that desire high, short-term profitability tend to set the product prices high.

Product characteristics: The product/service price may be set in direct proportion to the value and importance of the product to users, as well as the income levels of its target customers. Usually, a new product in its early life cycle sells at a high price, allowing the company to benefit from the product's novelty.

Marketplace characteristics: Companies set product prices in reverse proportion to the level of competition in the marketplace. The level of competition refers to the number of direct competitors, the number of indirect competitors marketing substitution products that offer similar value to customers, and the competitive counterstrategies (speed and intensity) that these competitors may exercise. Companies tend to set the product price high if the barriers to market entry are high. The barriers to market entry depend on lead time and resources—technical and financial, patents, cost structure, supply chain strategies and production experience. In addition, products with inelastic price-demand characteristics tend to carry a high price. A product has inelastic price-demand characteristics if a large price increase induces a small change in the quantity of the product demanded in the marketplace.

Distribution and production capabilities: Product availability to consumers depends on the company's product distribution capabilities. With strong distribution channels in place, companies may set the product price high, as quickly making products available to consumers represents a competitive strength.

Sales volume impacts the company's production experience. Companies with extensive production experience are known to generate products at a low unit cost. A lower product unit cost enables these companies to set a lower product price to gain market share.

The Boston Consultant Group studied manufacturing operations and discovered that there is a correlation between production volume and product unit cost. For every doubling of the production volume, the unit cost is whittled down by about 15%—or the 85% experience curve (Stern and Deimler 2006). (See Figure 8.14. Note that the horizontal axis in the figure is nonlinear.)

Companies with a faster time-to-market strategy are able to accumulate production experience more quickly, attain a lower product unit cost sooner, and sustain company profitability for longer periods of time.

Price–quality relationship: One important consideration in setting the product price is the cost–quality relationship perceived by customers. There is substantial evidence in business literature to indicate that customers tend to believe that "low-priced items cannot be good." Price is perceived to be an indicator of quality. Thus, product prices should not be set too low. There is a price threshold below which customers may raise questions regarding the quality, as indicated in Figure 8.15. The demand curve "Quantity T" illustrates a normal price–demand relationship in the absence of a price threshold, whereas the demand curve "Quantity A" contains a price threshold at about $30 per unit, below which the demand for the products starts to drop off as the perception of poor quality related to low price kicks in.

Relative position of power: Consumer products are typically marketed by a few major companies to a very large number of customers. For innumerable industrial products with high technological contents, the number of both producers and customers may be limited. The greater the number of sellers there are available for a given product, the weaker each seller's position in the marketplace will be. Similarly, the more buyers there are for a specific product, the weaker the buyers' relative market position will be.

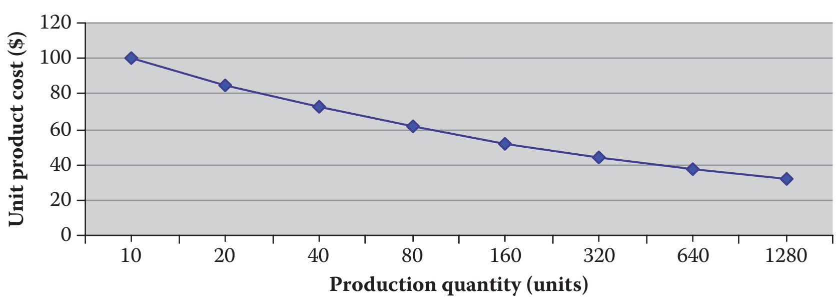

FIGURE 8.14
The 85% experience curve.

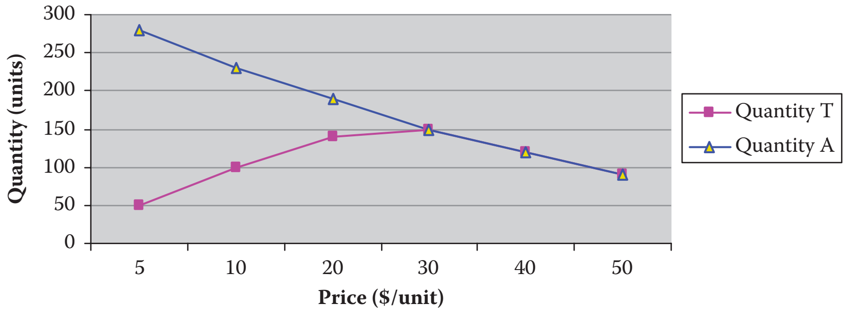

FIGURE 8.15
Price–quality relationship.

Less competition makes either sellers or buyers more powerful. The relative position power between buyers (customers) and sellers (producers) has an impact on product pricing, as illustrated in Figure 8.16. The final price offered by the sellers and accepted by the buyers is usually arrived at by a suitable negotiation or auction process.

If both buyers and sellers are strong—for example, when the U.S. government (customer) procures fighter airplanes from the defense industry (producer)—a final price is typically reached by a *negotiation* made up of a series of offers and counteroffers. A typical pricing arrangement may be cost plus a fixed percentage of gross margins.

When the sellers are strong (e.g., selling an original master painting, a porcelain vase from the Ming dynasty, or some other type of unique physical asset) and the buyers are weak, sellers tend to take advantage of their dominant supplier position by employing an auction. An *auction* is a bidding process by which buyers are forced to compete against each other by committing themselves to consecutively higher prices, with the final price being set by the highest winning bid.

If buyers are in a strong position (e.g., due to large transaction volumes), they force weak sellers to compete against each other in a reverse auction. A *reverse auction* requires the

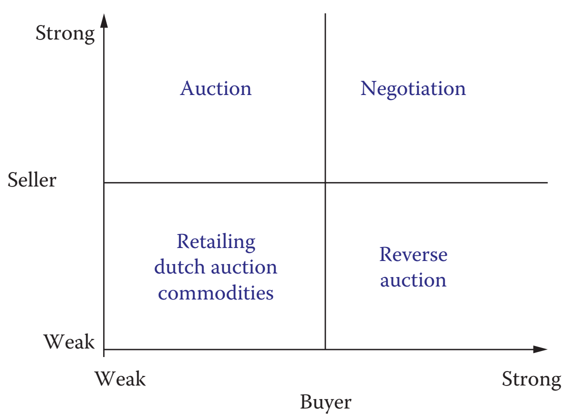

FIGURE 8.16
Relative power positions of buyers and seller.

prequalified sellers to submit increasingly lower bid prices within a fixed period of time (Preston 2014). The lowest bid defines the final price and the ultimate winner of the sales contract. Some large companies employ such pricing tactics to purchase high-volume supply items such as computers; paper and pencils; tires; batteries; and maintenance, repair, and operations (MRO) goods.

Finally, when both sellers and buyers are weak, products are usually not differentiable, and the product prices are highly depressed and fixed. Examples include various commodity products sold in retail stores. Some sellers (e.g., Land's End) may activate a *Dutch auction* to compete. In a Dutch auction, sellers slash the product prices by a certain percentage at a regular time interval (e.g., every week) until the products are sold or taken off the market. In this case, buyers compete against other "sight-unseen" buyers to seize the lowest possible selling prices (Stafford 2014).

The Internet has made many of these pricing processes much more practical and efficient to implement (Roberts and Zahay 2012). Because of its ability to allow sellers and buyers to rapidly reach other buyers and sellers, respectively, the Internet tends to weaken the relative power positions of both the sellers and the buyers, causing products to become increasingly commoditized, thus depressing product prices and intensifying competition.

Table 8.6 enumerates a number of other factors that have an impact on setting the product price.

TABLE 8.6

Other Factors Impacting Product/Service Prices

Factor	Skimming	Penetration
Demand	Inelastic	Elastic
	Users know little about service	Familiar service
	Market segments with different price elasticity	Absence of high-price segment
Competition	Few competitors	Keep out competition
	Attracts competition	Market entry easy
	Market entry difficult	
Objective	Risk aversion	Risk taking
	Go for profits	Go for market share
Service	Establish high-volume image	Image less important
	Service needs to be tested	Few technical service problems
	Short service life cycle	Long service life cycle
Price	Easy to go down later	Tough to increase later
	More room to maneuver	Little room to maneuver
Distribution and promotion	No previous experience	Existing distribution system and promotion program
	Need gross margin to finance its development	
Financing	Low investment	High investment
	Faster profits	Slower profits
Production	Little economy of scale	High economy of scale
	Little knowledge of costs	Good knowledge of costs

8.6.3 Pricing Methods

In setting product/service prices, companies broadly consider a number of the aforementioned factors. Several of these pricing methods are briefly discussed next (Vohra and Krishnamurthi 2012).

Cost oriented: Some companies set prices by adding a well-defined markup percentage to the product cost. This is to ensure that all products sold generate an equal amount of contribution margin to the company's profitability:

$$\text{Price} = \text{Cost} + \text{Markup}\left(\text{e.g., } 35\% \text{ of cost}\right) \tag{8.1}$$

Cost-plus contracts are often used for industrial products related to research and development (R&D), military procurements, unique machine tools, and other uses. Small sellers use cost-plus pricing to ensure a fair return while minimizing cost factor risks. Larger buyers favor this type of pricing so that they can push for vendor cost reduction via experience. Larger buyers may optionally offer to help absorb the cost risks related to inflation.

Often, sellers and buyers enter a target-incentive contract, which prescribes that, if actual costs are lower than the target costs, sellers and buyers split the savings at a specific ratio. On the other hand, if the target costs are exceeded, then both parties pay a fixed percentage of the excess; the buyers pay no more than a predetermined ceiling price.

Profit oriented: Other companies prefer to require that all products contribute a fixed amount of profit. This pricing method ensures that sellers realize a predetermined return on investment (ROI) goal.

$$\text{Price} = \text{Cost} + \text{Profits}\left(\text{e.g., in terms of ROI}\right) \tag{8.2}$$

Market oriented: Some companies set prices of certain industrial products, such as those requiring customization, to what the buyers are willing to pay. For example, companies strive to negotiate for the highest price possible and take advantage of the fact that product and pricing information may not be easily accessible. The continued advancement of Internet-based communication tools tends to make information just one click away, rendering this type of pricing method no longer practical in today's marketplace.

Companies may also price the products slightly below *the next-best alternative* products available to the customer. The companies that have exhaustively studied the next-best alternative products available to their customers would gain advantages in price negotiations.

Competitive bidding is often used by governments and large buyers. Usually three bids are needed for procurements exceeding a specific dollar value. Sealed bids are opened at a predetermined date, and the lowest bidder is typically the winner. Some industrial companies may engage in *negotiated bidding*, wherein they continue negotiating with the lowest one or two bidders for additional price concessions after the bidding process (e.g., a reverse auction) has been completed.

Valued-added pricing: Companies with extensive application know-how related to their industrial products may set product prices in proportion to the products' expected value to the customer. The product's value to the customer depends on the realizable improvement in quality, productivity enhancement, cost reduction, profitability increase, and other benefits attributable to the use of the product. Producers set the product prices high if there is a large value added by these products to the customer (Macdivitt and Wilkinson 2011).

Competition oriented: A common pricing method is to set prices at the same level as those of the competition. Doing so induces a head-on competition in the marketplace. In oligopolistic markets (typically dominated by one or two major producers or sellers and participated in by several other smaller followers), the market leader sets the price.

One well-known example of a competition-oriented pricing practice is target pricing. *Target pricing* was initiated and applied by many Japanese companies. Some American companies have now started to successfully apply this method (Nizam 2014). Target pricing is briefly addressed as one of several external benchmarking strategies in Section 5.3. The process of target pricing (see Figure 8.17) is as follows:

(a) Determine the market prices of products that are similar or equivalent to the new product planned by the company. Find all product attributes customers may desire. This is usually accomplished by a multifunctional team composed of representatives of such disciplines as design, engineering, production, service, reliability, and marketing. Select a product price (e.g., 80% of the market price) that makes the company's new product competitive in the marketplace. This is then the target product price.

(b) Define a gross margin that the company must have in order to remain in business.

(c) Calculate the maximum cost of goods sold (CGS) by subtracting the gross margin from the target product price. This is the target product cost, which must not be exceeded.

(d) Conduct a detailed cost analysis to determine the costs of all materials, parts, subassemblies, engineering, and other activities required to make the new product. Usually, the sum of these individual costs will exceed the target product cost previously defined. Apply innovations in product design, manufacturing, procurement, outsourcing, and other cost reduction techniques to bring the CGS down to or below the target product cost level.

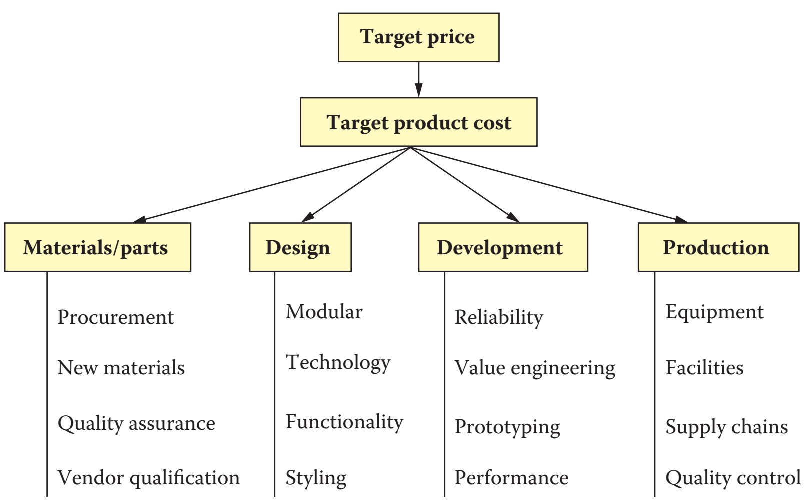

FIGURE 8.17
Target pricing model.

(e) Initiate the development process for the new product only if the target product cost goal can be met.

The target pricing method ensures that the company's new product can be readily sold in the marketplace at the predetermined competitive price, with features desired by consumers, to generate a well-defined profitability for the company. This method systematically evaluates low-risk, high-return investment opportunities because it forces the company to invest only when the commercial success of the product is more or less assured. Furthermore, it also focuses the company's product innovations on finding ways to meet specific and well-defined target product cost goals. It avoids the potential of wasting its precious intellectual talents in chasing ideas with no or little practical value.

Numerous companies use the aforementioned pricing methods. Product/service prices are usually set by the marketing department in consultation with business managers. Engineering managers are advised to become aware of these methods, but to defer pricing decisions and related discussions to the marketing department.

8.6.4 Pricing and Psychology of Consumption

Recent studies indicate that buyers are more likely to consume a product when they are aware of its cost. The more they consume, the more they will buy again and thus become repeat customers. One useful way to induce them to repeatedly consume the products is to remind them of the costs committed through the choice of payment methods. This is based on the assumption that the more often the customers are reminded of the payments, the more they feel guilty if they do not fully utilize the products they have paid for.

Gourville and Soman (2002) point out that a time payment plan better induces regular consumption of a product than a lump-sum prepayment (e.g., prepaid season tickets) at the same total value. This is because the time payments remind the buyers of the costs periodically and thus invoke the *sunk-cost effect* on a regular basis. The psychology of the sunk-cost effect is that consumers feel compelled to use products they have paid for to avoid the embarrassing feeling that they have wasted their money.

Credit card payments are less effective in inducing consumption than cash payments because cash payments require the buyers to take out currency notes and count them one by one; thus, they experience the "pain" of making payments.

In price-bundling situations, the more clearly the individual prices of products are itemized, the better the perceived sunk-cost effect will be. Breaking down large payments into a number of smaller ones, thus clearly highlighting the costs of individual products sold in the bundle, can enhance this effect.

Studies of membership rates at commercial wellness and fitness centers support this logic. It has been well documented that those members who pay the membership fees once a year use the facilities only occasionally. These members are the least likely to renew, in comparison with those who pay on a monthly basis. Similar observations are made in sports events in which holders of season tickets show up less frequently than those who buy tickets for specific sets of events.

These examples point out that companies can induce customers to become repeat customers by focusing on ways to encourage consumption. Only consumption lets customers experience the benefits of the product/service they have purchased. Without such favorable experience, they may not feel that they have good reasons to buy the products again in the future. Hence, besides providing a good bundle of value made up of price, product features, convenient and efficient order processing and delivery, and quick-response after-sales services, companies should devise ways to stimulate consumption as a strategy to cultivate and retain repeat customers.

Example 8.2

The company has been selling a number of products to customers. It is about to launch a new product with features far superior to any products currently on the market. One option is to price this new product at a large premium above the current price range so that the heavy development expenses can be readily recouped by the company. The other option is to set the price comparable with the existing range in order to retain customer loyalty. What is your pricing advice to the company?

Answer 8.2

Hold a focus group to find out the potential response of customers to the new product's features. Are these features of real value to them? How much more are they willing to pay for these new features? Exciting new features from the manufacturer's viewpoints may not be as exciting to customers. Should customers appreciate the new features, then it is advisable to apply the skimming strategy and set a high price for the new product. This is also the principle of value pricing. Furthermore, doing so will avoid "cannibalizing" the existing products of the company.

An efficacious promotional campaign is essential to heighten product awareness. Keep monitoring the response of the market. If the market response is poor, cut down the product price slowly to induce more demand.

8.7 Marketing Communication (Promotion)

Marketing communication is intended to inform the target customers of the features and benefits of the company's offerings (Clow 2013; Belch and Belch 2011). Product promotion follows a well-planned process (see Figure 8.18) for who says what to whom, in what way, through which channel, and with what anticipated outcome.

8.7.1 Communication Process

Companies select communicators who are publicly recognized and who have trustworthy images, as these speakers tend to induce public acceptance of their messages. Examples include Bob Dole for Viagra, and Yao Ming for basketball-related items.

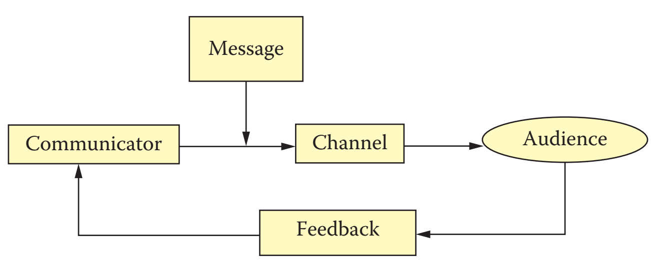

FIGURE 8.18
Promotion process.

Messages may be in various forms, including slogans. A slogan is a brief phrase used to get the consumer's attention and acts as a mnemonic aid. Successful slogans typically represent a symbolization of product features in terms of the customer's wants and needs (such as information, persuasion, and education). Examples include "Ring around the Collar," "Where's the Beef?," "You are what you know," "One investor at a time," "Our Insights are Your Guide," "Predictive Analytics: Drive Better Decisions with Data," "See a New Way to Discover Insights – Smarter Decisions are Made with IBM," and "Vanguard Lets You Keep More. That's Our Low-Cost Advantages."

Channels of communication are a specific means to foster market advertisement. In general, there are two types of communications channels: the marketer controlled and the consumer controlled. The *marketer-controlled* channels include advertisements placed by the producers in trade journals, national television programs, distribution brochures, advertisements by technical salespeople, industrial exhibitions, and direct-mail marketing. The *consumer-controlled* channels include private communications by word of mouth, news reports, and others sources of information perceived to contain no conflicts of interest.

The customers are the target for marketing communications. When selecting communications channels to reach specific consumers, the consumers' characteristics, media habits, and product knowledge must be taken into account. Consumers' characteristics include socioeconomic status, demographics, lifestyle, and psychology. For industrial customers, characteristics include market capitalization, market share, and stability of financial position. Media habits point to sources of information preferred by the customers (e.g., types of magazines and TV programs). Product knowledge is the consumers' understanding and appreciation of the values offered by the producers.

Some companies invest a considerable amount of effort in educating their consumers. A case in point is the known practice of some drug companies that sponsor large-scale clinical studies conducted by universities and other independent organizations. The purpose of these funded studies is to produce results for publication in technical journals from which consumers gain product knowledge in ways preferred by the sponsoring drug companies.

The impact of marketing communications on products/services may be short term or long term. The short-term impact is related to recall, recognition, awareness, and purchase intention with respect to the offerings in question. The long-term impact is reflected in the purchases by customers and brand loyalty with repeat purchases. Several factors influence the effectiveness of marketing communication, namely, timing, price, product availability, responses by competition, product warranty conditions, and customer support service.

Marketing communication brings about heightened product/service awareness, as an improved familiarity with the offerings induces more people to purchase them at the current price levels.

8.7.2 Promotion Strategy

Product/service promotion may be pursued by either causing the consumers to want to pull the products/services from the supply chains or allowing the producers to push the products/services to the consumers through the supply chains. Many companies practice both strategies.

In a *pull* strategy, the consumers go to retail stores to ask about the product/service because they have been informed of its values by advertisements and other promotional efforts of the sellers. In this case, the product or service is presold to the consumers, who practically pull the products through its distribution channels (see Figure 8.19).

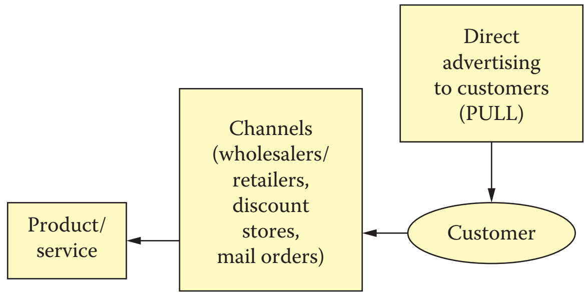

FIGURE 8.19
Pull strategy.

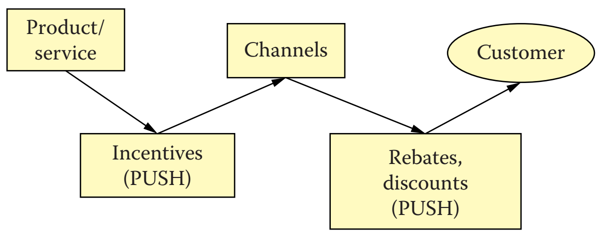

FIGURE 8.20
Push strategy.

In exercising a *push* strategy, sellers introduce incentive programs (e.g., factory rebate, sales bonus, telemarketing, rebate selling, door-to-door sales, or discount coupons) to push products/services onto the consumers. Figure 8.20 illustrates the push strategy. Table 8.7 compares these two promotional strategies.

Consumer and HT products are promoted differently. To bring the most convincing marketing messages to the intended users, marketers for HT and consumer products use different channels. For examples, trade shows, users groups, trade journals, and the Internet are typically used for HT products, whereas print media, radio, TV, and the Internet are used for consumer products. Advertising is less important for HT product and more important for consumer products. The consumer segments are more numerous for HT products than for consumer products. Companies spend less marketing resources and place more extensive focus on promoting HT products than on consumer types. Brand is critically important for promoting consumer products than for HT types.

TABLE 8.7
Comparison of Two Promotion Strategies

	Push	**Pull**
Communication	Personal selling	Mass advertising
Price	High	Low
Service's need of special support	High	Low
Distribution	Selective	Broad

8.7.3 Internet-Enabled Communications Options

Communications among sellers, intermediaries (e.g., distribution partners), and buyers have been significantly enhanced by the Internet (Lewis 2009). Figure 8.21 presents four specific modes of communication.

Manufacturers and suppliers usually set up the intranet to communicate with intermediaries (business to business, or B-to-B). Intermediaries may create their own websites and other tools to communicate with customers in a business-to-customers (B-to-C) mode. A direct communication between manufacturers, suppliers, and customers can be readily fostered by the company's websites, call centers, and other means for order processing, inquiry coordination, problem solving, and additional mission-oriented activities such as customer surveys, focus groups, and product testing.

The virtual market is a segment of the Internet domain where third-party portals (e.g., Google, Yahoo, and other search engines), auction sites (e.g., eBay), and e-commerce marketplaces (e.g., ChemConnect) actively provide channels to access information useful to all parties involved (manufacturers, suppliers, intermediaries, and customers).

In the B-to-B markets, businesses buy essentially two kinds of goods from other businesses, namely, manufacturing inputs (raw materials, equipment, and components) and operational inputs (MRO goods, office supplies, spare parts, travel services, computer systems, cleaning, and other services). They buy these goods by systematic sourcing or spot sourcing. Electronic hubs provide the useful functions of aggregation and matching.

Companies invest efforts into creating websites that offer product information and facilitate sales transactions. However, studies show that these efforts have not yet returned the high profitability generally anticipated from such a marketing approach. The basic reason is that it remains unpredictable how frequently new and repeat customers visit these websites and then actually place orders.

A new way of thinking is offered by Hackley (2013), who suggests that the focus of e-commerce should be shifted from contents to context. He believes that contextual marketing (bringing the marketing message directly to the customer at the point of need) is the key. A number of contextual marketing examples are described next.

Johnson and Johnson's banner ads for Tylenol (an over-the-counter painkiller drug) show up on e-brokers' websites whenever the Dow Jones Industrial Average falls by more than 100 points on a given business day. They anticipate that investors will have headaches and thus will need Tylenol when they see their stocks lose money. The marketing message

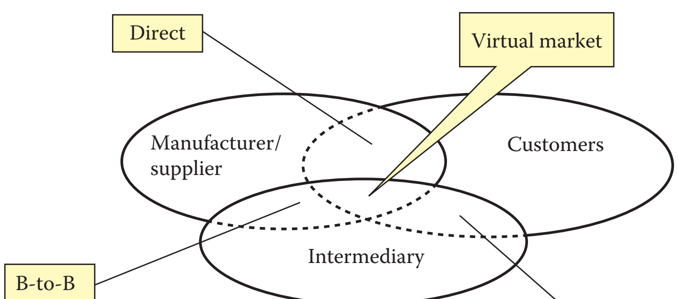

FIGURE 8.21
Modes of communications. (From Griffith, D.A. and Palmer, J.W. *Bus. Horizons*., 42, 1, 1999. With permission.)

is brought out in the correct context as a way to reinforce its relevance and to offer transactional convenience at the right time.

CNET and ZDNET websites attract diverse visitors interested in computers. Instead of placing banner ads in these CNET and ZDNET sites to redirect visitors to its own website, Dell offers product information directly within the CNET and ZDNET websites. Dell piggybacks on CNET's and ZDNET's relationship with its computer-savvy customers in order to promote Dell's own customer-acquisition economics. Doing so holds the customer's attention on computer design and offers competitive design choices and speedy order processing at the optimal moment. Here, the tactic used by Dell is to insert itself into a preexisting customer relationship at the right time and place.

Several search engines (e.g., Google, Yahoo, AOL, MSN, Lycos, AltaVista, and HotBot) practice contextual marketing. When a user conducts a keyword search, the output is typically placed in a left-aligned column under the heading "Matching Sites" and rank ordered according to hit frequency. Quite frequently, several items under the heading "Sponsored Links" are placed on top of the "Matching Sites" column. These are paid advertisements related to the keywords entered by the user. They are there to offer contextual marketing messages relevant to the expressed interest of the user.

As web-based technologies continue to advance, the Internet will become more accessible by many more users from almost anywhere and at any time, causing them to become overwhelmed by information and choices. Bringing the right marketing information to the customer at the point of need is likely to become a critical success factor for various companies in marketing communications.

8.8 Distribution (Placement) Strategy

Numerous organizations are involved in moving products and services from the points of production to the points of consumption. As indicated in Figure 8.22, some companies may engage intermediaries (e.g., wholesalers and retailers) to distribute their products, while others may elect to interact directly with their customers (Dent 2011). Distribution channels serve very useful functions, which include:

Transportation: Overcoming the spatial gap between the producer and the user
Inventory: Bridging the time gap between production and usage
Allocation: Assigning quantity and lot size

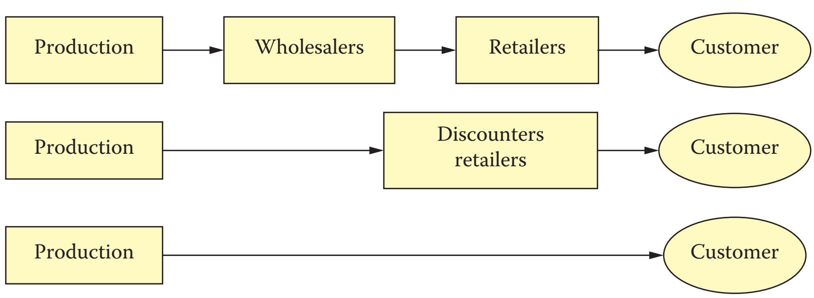

FIGURE 8.22
Distribution options.

Assortment: Grouping compatible products for the convenience of users, as qualified technical representatives could sell several product lines

Financing: Facilitating timely possession of products

Communication: Providing product information and feedback to and from consumers

In recent years, distribution channels for some products/services have experienced significant changes due to upgraded logistics, transportation technologies, and advancements in communications technologies. For example, the Internet has enabled many producers to deliver digitized products—books, newspapers, magazines, music products, video products, and travel services—directly to consumers, thus bypassing the traditional store-front intermediaries. Because of the use of sophisticated websites from which extensive product/service catalogs may be accessed, retail stores have also lost some of their traditional importance for selling physical goods—clothing, cars, appliances, and so forth.

Furthermore, logistics companies such as the United Parcel Service (UPS) are constantly improving their transportation capabilities and satellite-based communications system technologies in order to deliver physical goods anywhere in the world while allowing a constant tracking of the status of consumer orders.

Warehouse design is expected to increasingly involve gantry robots and complex process optimization for constantly improving the efficiency of automated high-volume operations.

8.8.1 Types of Distribution

Traditionally, distribution is classified as either intensive, exclusive, or selective. In *intensive distribution*, products are stocked in diverse outlets, such as hardware stores, department stores, and catalog rooms, for wide distribution. This type of distribution is particularly suitable for consumer products of low technology and differentiation features. Examples include films, calculators, electric fans, books, and CDs. With *exclusive distribution*, certain products are distributed only through exclusively designated outlets. This allows producers to retain more control over price policy, promotion, credit, and service, as well as to enhance the image of the products. Examples include dealerships for specific cars and qualified product centers for brand-name PCs. The *selective distribution* is suitable for certain other products, the sales and service of which require special technical know-how and training. Examples include electronic instruments, HT equipment, and custom software.

Services, such as health care, business consulting, financial advisement, and education, are usually offered, selectively, at specifically designated retail stores.

8.8.2 Organizational Structures

In order to enhance distribution effectiveness, some companies elect to exercise more control over the supply chain by integrating forward. Others have elected to integrate backward.

A *forwardly integrated* organization strives to control the distribution channels leading to the customers. For the purpose of securing a larger market share and exercising more direct control, a producer may attempt to build its own retail outlets. Doing so allows the producer to gain direct access to customers and thus to benefit from their feedback. This type of organization is also favored by providers of services.

On the other hand, a *backwardly integrated* organization seeks to control the value chain leading backward to production. For example, some retailers or wholesalers may attempt to own specific production facilities or to outsource production for creating private-label products in order to market products with their own brand names, reduce costs, ensure supply, and control quality.

8.8.3 Impact of E-Commerce on Distribution

The Internet has significantly modified the traditional classifications of distribution. Many consumer products, as well as certain HT products, are now marketed directly through a company's websites, including order processing and after-sales services. As a consequence, many intermediate companies currently involved in distributions—wholesalers, discounters, and some retail stores—are gradually being forced out by Internet-enabled e-commerce companies and by the increased involvement of efficient and fast-responding logistics providers.

One immediate impact of e-commerce is the reduction of the final product price and product delivery schedule, both of which are beneficial to end users.

Example 8.3

Customers' wants and needs are regionally different for products intended for global markets. How can a centralized, concurrent engineering team develop a product that will serve as the common "platform" for global markets?

Answer 8.3

One option is to segregate the mechanical aspects (functionality) of the products from their aesthetic aspects (look and feel). General Motors is accomplishing this challenging objective by

1. Building identical assembly plants for Buick cars at four global locations
2. Outsourcing major subassemblies to local industries to minimize import duties and to satisfy local content laws
3. Standardizing the technical specifications so that parts supplied by one region can be readily rerouted for use by another, in order to balance loads due to market demand fluctuation, labor disputes, governmental regulations, and other unpredictable events
4. Modifying design to account for local market conditions relative to cultural preference (e.g., car names in local languages, styling preferences, purchase habits, and colors)
5. Retaining centralized concurrent engineering approaches to facilitate global business strategy and scale of economy, while being flexible enough to adjust to local needs

Example 8.4

The company plans to enter a new global market. It has three products currently selling well in its home country. The company's brand name is strong and internationally well recognized.

Current market research indicates that the segments for these three products in the targeted global market are of different sizes, growth rates, and profitability for the foreseeable future. Other product characteristics are included in Table 8.8.

Which one product should be selected to penetrate the targeted global market? Why? If the company has the required resources to market all three products in the targeted global market, in what priority order should the company proceed?

TABLE 8.8

Product Characteristics

	Product A	Product B	Product C
Segment size ($)	Small	Medium	High
Segment growth rate	Medium	Medium	Low
Profitability	High	High	Medium
Service value to customers	High	Medium	Medium
Brand strength	High	High	High
Delivery/distribution efficiency	Low	High	Medium
After-sales support activities	Medium	Medium	High

Answer 8.4

To enter a global market, the company must examine two key questions: (1) How attractive is the target market segment to the company, and (2) how acceptable is the product offered to the customers in the target segment?

The attractiveness of a market segment to a company is generally defined by three factors, namely, segment size, segment growth rate, and profitability. By using the information presented in Table 8.8, it becomes clear that the ranking based on "attractiveness" should be Product B first, with Products A and C sharing the second spot.

How acceptable the company's product is to the customers depends on the product value as perceived by the customers, the brand strength of the product, the delivery or distribution efficiency that affects the product's availability to the customers, and the ease with which customers could obtain an after-sales service. Based on the "acceptability" criterion, the ranking of these products should be Products B, C, and A.

Since both the "attractiveness" and "acceptability" criteria are equally important, we need to come up with a combination ranking, which says that the company should select Product B as its first choice to enter the global market, followed by Product C, and then Product A.

8.9 Physical Evidence

Physical evidence refers to the physical setting in which a service is to be offered, delivered, or consumed. Customers form a brand image of the service vendor by observing the physical layout, decor and color, design details, equipment capabilities, the status of facilities that support the service delivery and enhance the communication of messages (e.g., service availability, customer satisfaction) to other potential customers, and by judging the extent to which the physical setting meets or exceeds their expectations.

Singapore Airlines has maintained the same uniform for its stewardesses for 25 years. McDonald's and Citibank design its retail branches to look and operate the same way in any location.

8.10 Process Design

By process, we refer to the chosen work procedure, inter-unit collaboration, and the flow of activities by which services are delivered, service consumption is facilitated, and customers' problems are solved, as measured by such metrics as speed, convenience, efficiency, and the extent of empowerment enjoyed by the customer-facing staff. Customers gain an overall impression regarding the equality of the customer-focused process being practiced.

8.11 People

Many people are directly or indirectly involved in the production and consumption of services (knowledge workers, employees, management, and other customers), who may add to the value of the service offering. Following the Value Profit Chain model (Heskett et al. 2002), recruiting the right customer-facing staff; preparing them with proper training in interpersonal skills, aptitude, and service knowledge; empowering them to take care of customers; and compensating them well are all essential models toward achieving customer satisfaction and corporate profitability.

Example 8.5

In this chapter, we talked about the marketing elements, which include: (1) product/service, (2) price, (3) promotion (advertising), (4) placement (distribution), (5) physical evidence, (6) process design, and (7) people.

When marketing products, it is usually sufficient to focus on the first four of these marketing elements. On the other hand, all seven marketing elements are deemed important when marketing services. What are the underlying reasons for the last three (e.g., #5, #6 and #7) marketing elements to be particularly important for marketing services?

Answer 8.5

Companies address all seven marketing elements (7Ps) when marketing services. The principal reason for this is that services (e.g., health care, business consultation, financial services, leisure and travel, insurance, and others) require a much higher degree of customization in the process of specifying, producing, delivering, and offering after-sales support than products (e.g., automobiles, computers, and appliances). Because of these service-specific characteristics, customers are exposed to the vendor's performance in (a) physical evidence, (b) process, and (c) people to a much greater extent, making these elements more important in affecting the customer's satisfaction than in marketing products.

Thus, to be customer focused, service companies pay more attention to (a) physical evidence related to facility design, office layout, and employee uniforms; (b) processes in problem solving and conflict resolutions affecting customers; and (c) people—by choosing, training, and monitoring customer-facing staff to ensure friendliness and customer-centered attention.

8.12 Customers

Customers are important to any product/service company. A company's marketing program needs to focus on the targeted customers, understand them, practice the right strategies to win them over, create emotional bond with them, improve interactions and enhance their loyalty, and continue to expand the number of satisfied customers by asking the right customer survey questions.

8.12.1 Customer Focus

Customer focus is aimed at knowing the real needs of target customers, past, present and future. It requires the collaboration of many employees as well a functioning support organization to make it happen. Based on a study of the Royal Bank of Canada, Gulati and Oldroyd (2005) suggest a four-stage coordination process for service companies to become customer focused, namely, (1) communal, (2) serial, (3) symbiotic, and (4) integral coordination. For example, the primary organizational objective is to (1) collect information, (2) gain insight into customers from past behavior, (3) develop an understanding of likely future behavior, and (4) conceive a real-time response to customer's needs.

Getting closer to customers is a journey the entire company must take, not just the marketers and customer-facing staff. A firm cannot be oblivious to the changes in customer perspectives of its product/service in the marketplace. It requires corporate leadership and company commitment to get useful results.

8.12.2 Customer Acquisition in Business Markets

The benefits derived by acquired customers in business markets belong to four categories.

1. Tangible financial benefits
2. Nontangible financial benefits: Conducting pilot projects, money-back guarantees for nonperformance, pay for performance contracts
3. Tangible nonfinancial benefits: Corporate reputations, global scale, innovation capabilities
4. Nontangible, nonfinancial benefits: Something the vendor does extra for consumers to enhance convenience, customer relationship, or services offered, above and beyond contracts

According to Narayandas (2005), to acquire customers, companies must be on par with rivals with respect to tangible financial benefits. They need to use tangible nonfinancial benefits to differentiate and shift customer's focus from tangible benefits to nontangible, nonfinancial ones (e.g., free services that reduce customers operating expenses); and suggest ways to make customer's process more efficient, thus earning the trust of the customers.

Consumer markets and business markets are quite different. Table 8.9 shows the difference.

When marketing to business customers, companies need to know that business decisions are typically made by a team of people. Each team member could have one or more specific needs. Knowing who these people are and what each of them is looking for is of

TABLE 8.9

Differences Between Consumer and Business Markets

#	Characteristics	Consumer Markets	Business Markets
1.	Segmentation of market	Critical	Not important—"segment of one"
	Branding	Important	Not important
	Focus of communication	Novelty of features	Solving customer's specific problems
2.	Number of buyers	Large	Small
3.	Transaction value	Small	Large
4.	Production	Mass-production	Customized to individual needs
5.	Value	Customer's perception	Defined by customer's usage
6.	Sales process	Brief	Elaborate (long and complex)
7.	Retailing strategy	Important	Not important
8.	Focus of sales efforts	End users	Group of decision-makers

Source: Narayandas (2005).

critical importance to the seller. The vendor must become sensitive to these needs and be prepared to address all of them adequately.

8.12.3 Moments of Truth in Customer Service

The "moments of truth" are times when a customer invests a significant amount of emotional energy in the outcome of a service transaction with producers. Examples of such moments include (1) a customer has a problem encountering an unexpected difficulty in applications, receiving a hold on a check, and so on; (2) a customer has a need to get a quick answer; (3) a customer receives financial advice (good or bad); and other suggestions. If these moments are handled positively, customers are likely to create an emotional bond with the producers and subsequently increase their future commitment to the producer's services. The study of Beaujean et al. (2006) shows that the customer experience, related to other humdrum service interactions that involve unelevated emotional energy, is of little consequence.

Management must therefore support and develop frontline staff to enable them to handle such "moments of truth" by way of empowerment, nurturing the right service mind-sets, and acquiring the necessary service knowledge, while de-emphasizing the efficiency improvement of other manual transactions. Developing deeper and long-lasting relationships with customers is key to sustaining long-term profitability (Beaujean et al. 2006).

8.12.4 Customer Interactions and Loyalty

The interactions between customers and companies play a very important role in securing marketing success. Creating a pleasant experience for customers (e.g., in order processing, service information dissemination, inquiry coordination, problem solving, after-sales support service, and market surveys) is crucial for customer retention. Winning customer cooperation in offering much-needed feedback is vital to the company's service development. Management of customer relations is thus an important corporate responsibility.

Some lessons from the past are noteworthy. Customer interactions are not limited to marketing. Many other functions of the company are involved, including support service, accounts receivable, legal, engineering, manufacturing, and shipping. Empowered employees can act on behalf of the company to satisfy customer requirements. Adequate support infrastructure must be established to enable employees to perform the tasks in an innovative and customer-responsive manner.

The major payoff for a successful customer interaction program is customer loyalty. Customer loyalty contributes to company profitability. Studies indicate that increasing the customer retention rate by 5% raises profits by 25%–95% (Reichhold and Shefter 2000). Loyal customers are valuable because they buy more, refer their pleasant experience to new customers, and offer consultations to these new customers at no cost to companies.

To build customer loyalty, the customer interaction strategy must be focused on creating trust. Amazon.com is viewed by many as one of the most reliable and trustworthy websites on the Internet. It registers user preference, becomes smarter over time at offering services tailored to each user, provides one-click convenience for purchasing items, and delivers the ordered services free of errors. It is reported that 59% of Amazon.com sales are derived from repeat customers, roughly twice the rate of typical "brick-and-mortar" bookstores.

Vanguard Group, a company that markets index-based as well as specifically managed investment funds, offers timely and high-quality financial advice on its website and does not attempt to hard sell any specific service. Its customer interaction strategy is focused on building trust. "You cannot buy trust with advertising or salesmanship; you have to earn it by always acting in the best interest of customers," says Jack Brennan, Vanguard CEO.

eBay is actively practicing the referral-based business, having about 50% of its new customers referred by loyal customers, who are also its helpers. One major concern in the business of auctioning used merchandise is reliability and fraud prevention. eBay asks each buyer and seller to rate each other after every transaction. The ratings are posted on the website. Every member's reputation becomes public record. Furthermore, eBay insures the first $200 for each transaction and holds the money in escrow until the buyer is satisfied with the received merchandize.

How is trust related to profitability? Studies show that, in some businesses, customers must typically stay on board for at least two to three years just for the companies to recoup their initial customer-acquisition investment. In other words, for companies to achieve profitability, customers must be loyal enough to stay beyond the break-even period. A large percentage of customers defect before many new companies reach this break-even point. Reichhold and Shelfter (2000) showed that companies with consumer electronics and appliances products spend on average $56 to acquire a new customer, their break-even point is four years, and 60% of their customers defect before reaching the break-even point. For groceries and apparel companies, their customer-acquisition costs are $84 and $53, their break-even years are 1.7 and 1.1, and their percentages of customer defection before reaching the break-even point are 40% and 14%, respectively.

A large number of companies are successful in planning and implementing strategies to interact effectively with customers. According to Dorf et al. (2002), these companies identify and prioritize customers, define their needs, and customize support services to fit these needs. They reap the benefits of increased cross-selling, reduced customer attrition, enhanced customer satisfaction, minimized transaction costs, and sped-up cycle times.

Companies known for their success in relationship marketing include Pitney Bowes, Wells Fargo, 3M, Owens Corning, British Airways, Hewlett-Packard, and American Express.

Customer loyalty is won, not by technology, but through the delivery of a consistently superior customer experience. It requires a well-designed customer interaction strategy that is supported by companies with a firm corporate commitment.

8.12.5 Customer Feedback

A great number of customer satisfaction surveys contain too many questions. According to Reichheld and Markey (2011), the ultimate question to ask is: "How likely are you to recommend this company to a friend or colleague?" Score the results on a 0–10 scale and classify the responses as follows:

1. Loyal promoters (9s and 10s)
2. Passive customers who do business with the company (7s and 8s)
3. Detractors (6s and below)

The net promoter score (NPS) is defined as the percentage of promoters minus the percentage of detractors. For example, if the promoters are 35%, passive customers are 50%, and detractors are 15%, then the NPS is 20%. Based on a survey conducted by Bain & Company, companies with an NPS in the range of 50%–80%, are superior in achieving good profits. Examples of these high-NPS companies include: USSA (82%), HomeBanc (81%), Harley-Davison (81%), Costco (79%), and Amazon.com (73%).

Obviously, the key to growing a business is to have more promoters and less detractors. Since the company already has a relationship with these "promoter" customers, it should solicit information from them in order to understand exactly where the company is succeeding and how to apply this information toward ensuring the company's ongoing success. They should contact detractors as well, to find out what the company can do to improve their service offerings. Reichheld and Markey (2011) believe that business growth can only be sustained over a long period based on the loyalty of satisfied customers and customer-focused promotions. To achieve success, companies must always practice the *Golden Rule*: to treat others as you would want to be treated in return.

This concept appears to be consistent with the "Value Profit Chain" model (Section 8.5.6) in that satisfied customers will not only increase spending for themselves, but also recommend that their friends follow suit. The way to ensure customer satisfaction is to adopt company policies that make for happy and loyal employees, who will in turn promote company's brands leading to long-term corporate profitability.

Example 8.6

Over the years, New Health Company spent a considerable amount of effort in developing and testing a new drug intended for reducing the LDL (bad cholesterol) and raising the HDL (good cholesterol) of patients with cardiovascular disease. After having passed the Phases 1, 2, and 3 trials, the drug received Food and Drug Administration (FDA) approval for marketing to the public. There are some known drugs already in the marketplace for this type of disorder, which affects millions of people in the United States alone. The size of the overall market for cardiovascular drugs is estimated to be about $25 billion annually. Devise a marketing plan to bring this new drug into the U.S. marketplace.

Answer 8.6

The marketing plan should consist of four parts, corresponding to the 4Ps of marketing products, namely, product, price, placement (distribution), and promotion.

As a new product, the drug in question offers the useful features of lowering LDL and raising HDL, a very powerful combination to combat heart disease, based on the current state of clinical knowledge. A direct competitor is Lipitor, which has the same beneficial effects as the new drug. Furthermore, Crestor, together with Niacin, are also known to produce this combination effect. It is important for the company to delineate any differences this new drug might have regarding (1) side effects, (2) potential long-term health hazards, (3) lower frequency of taking the drug, and (4) longer effectiveness. These differences must be clinically verifiable by way of large-scale clinical studies.

Pricing is an important issue to some patients. The new drug should be retail-priced at a level slightly lower than its current competitors. Aggressive contracts should be entered into with major insurance carriers, mail order drug companies, AARP prescription drugs program, and others to allow volume-based discounts.

Promotion is rather critical for a new drug entering an existing market. Key targets are patients, physicians, and insurance carriers. Patients need to become aware of the unique benefits of this new drug via TV, magazine articles, and web-based advertisement, so that they could "pull" this drug from the supply chains. The message should emphasize its distinguishing features in view of the existing competition. Physicians must be convinced via trade shows, clinical studies, and journal articles of its relative merits, so that they would be willing to suggest/prescribe this new drug and allow brochures to be distributed through their offices. Frequent publication of supporting articles in highly reputable journals such as *New England Journal of Medicine*, *Journal of American Medical Association*, *Journal of Cardiology*, *Circulation*, and others will attract the attention of physicians. Insurance carriers need to be convinced of the benefits of this new drug in order for them to be willing to place it in their formularies.

The distribution of this new drug would follow the usual wholesale channels, as it is a prescription drug authorized by physicians and available only from pharmacies.

New Health Company should monitor the market constantly and adjust its marketing program accordingly.

8.13 Other Factors Affecting Marketing Success

There are several other factors that may affect the marketing success of any company.

8.13.1 Alliances and Partnerships

Nowadays, companies increasingly realize that they do not always possess or cannot cultivate internally all competencies needed to compete in the world markets, under the current constraints of resource and time. Examples of these constraints may include (1) the market access is unattainable, (2) the technology is unaffordable, and (3) the time to market is too long. Forming business partnerships and alliances may have become increasingly necessary for many companies to compete effectually and to constantly deliver value to their customers. For companies to succeed in the marketplace under these circumstances, the marketing concepts must penetrate to all members of the partnerships and alliances (Humphries and Gibbs 2009). The following examples illustrate the working of such supply chain partnerships and alliances:

1. Calyx and Corolla formed a network of partnerships to provide the seamless delivery of fresh flowers from grower to final customer in one-fourth of the time required by the traditional channels.
2. Dell teamed up with parts manufacturers and assembled computer systems in their own plants. Then Dell linked with logistics partners to deliver custom-designed personal computers (PCs) within three days to customers anywhere in the world. The Dell model was highly successful when implemented, allowing Dell to attain a high worldwide market share of PCs.

Partners must appreciate that synergistically, benefits may be realized when all members of the alliance embrace the marketing concept and come to recognize the importance of creating superior customer value by joining hands.

8.13.2 Organizational Effectiveness

Marketing success is also influenced by how effectively the company operates. In general, organizations with a less rigid structure have a higher likelihood of becoming more customer focused, technologically innovative, and market responsive. Certainly, any conflicts between internal functions—manufacturing, design, engineering, and marketing—must be minimized. Technology for mass customization requires an integration of R&D, procurement, customer relations management, and supply chain management to achieve a high degree of customer satisfaction (Levenson 2015; Biron 2014).

Above all, company management must apply discretionary resources (e.g., R&D, production capacity, human resources, organizational expertise, and information services) to the right combination of strategies (e.g., marketing, product, distribution, promotion, and price) so that maximum strategic marketing leverage can be achieved to capture opportunities offered in the marketplace. Figure 8.23 illustrates this core concept of organizational effectiveness.

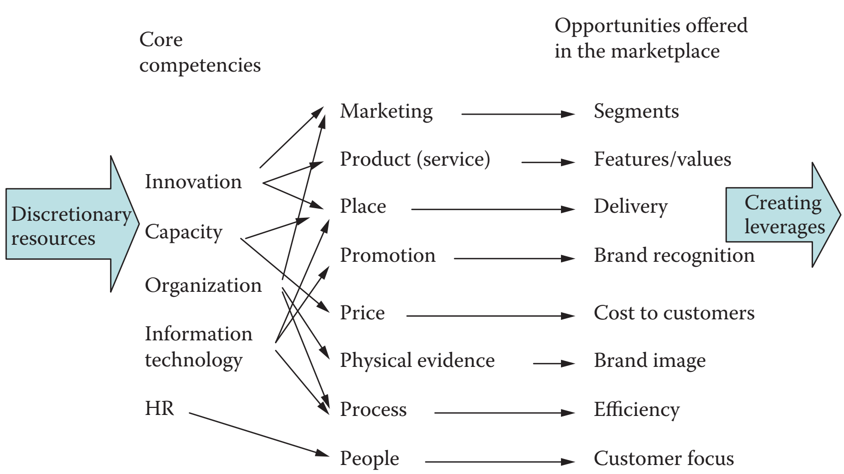

FIGURE 8.23
Organizational effectiveness.

8.13.3 Chasm for Marketing HT Industrial Products

For marketing HT industrial products, there are five general customer segments to consider (Figure 8.24):

1. Innovators (Techies): Excited with new innovative technologies
2. Early Adopters (Visionaries): Look for strategic value, compelling applications
3. Early Majority (Pragmatists): Willing to use new technologies, look for value and take some risks
4. Late Majority (Conservatives): Focus on easy to use, take no risks
5. Laggard (Skeptics): Suspicious to anything of being technologically new

HT product marketing relies heavily on word-of-mouth references. Customers in the Innovators and Early Adopters segments are likely to be technical specialists who are by nature excited about things technologically new. Moore (2014) believes that customers in the Early Majority group are more conservative in viewing new technologies and thus may not be readily influenced by the views of Innovators and Early Adopters This could represent a major chasm for HT product vendors to overcome, when marketing HT products to the mainstream customers in Early Majority and Late Majority groups.

To overcome the noted chasm, companies marketing HT products are advised to follow these strategies:

1. Create whole products (core products plus extensions)
2. Focus on compelling reasons to buy
3. Emphasize product differentiation in the marketplace

Example 8.7

Engineering refined the design specifications of a product as originally recommended by marketing. Manufacturing made additional changes to the product design in order to fabricate the product automatically. Unfortunately, the product did not sell in sufficient quantities to make it a success. Explain the possible reasons.

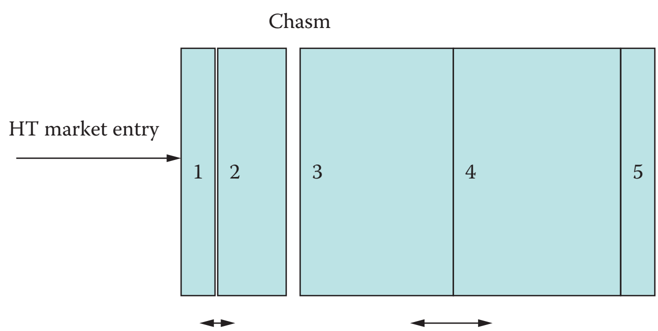

FIGURE 8.24
Chasm for marketing disruptive products.

Answer 8.7

The product features defined initially by the marketing department may not be exactly what the majority of customers want. Product testing is a critical step to fine-tune product design. The selected method of production does not readily accommodate an adjustment of product features, even if they are identified by feedback from the marketplace. The manufacturing of the product should be based on demand to ensure market acceptance, not based on production technology, which is aimed at cost reduction.

Skipping the product testing step with customer feedback and applying the automatic production method too soon are two likely reasons for the noted failure.

8.14 Conclusion

This chapter covers many important issues related to the marketing of a company's products and services. Engineering managers should understand the overall objectives of the firm's marketing efforts and become sensitive to various marketing issues affecting engineering. They should become well versed with marketing terminology and elements of the marketing mix (7Ps), namely, product, price, promotion, placement (distribution), physical evidence, process design, and people. It is important for engineering managers to accept the fact that marketing involves a lot of uncertainties associated with consumers' perceptions, competitive analyses, and market forecasting. They need to wholeheartedly adopt customer orientation in planning and implementing all engineering efforts in support of marketing. They must strive to work closely with marketing personnel and remain supportive of the overall marketing efforts by providing high-quality engineering inputs to the firm's marketing program. As Cyrus Eaton said, "What counts in any system is the intelligence, self-control, conscience and energy of the individual."

Obviously, the engineering inputs most useful to marketing are related to products/services and associated production and customer support activities. These include specifying and designing novel product/service features to be of value to customers; utilizing technologies to confer competitive advantages in time to market, quality, reliability, and serviceability; and delivering after-sales technical services needed to ensure customer satisfaction.

Engineers are also expected to contribute diligently by improving and managing the production process, utilizing resources (labor and materials), controlling quality, and estimating product cost accurately with the activity-based costing (ABC) method. Engineers may also get involved in training salespeople, making technology-centered presentations before customers, conducting industrial exhibits, and evaluating customer feedback related to new product features.

Having learned the marketing concepts and been exposed to the complex marketing issues reviewed in this chapter, engineering managers will be able to appreciate the difficult but critically important functions of marketing and can become more effective in interacting with marketing management.

Marketing and innovations are two principal activities of any product-based and profit-seeking organization. STEM professional already know how to innovate. If they also learn how to market, the combination of these capabilities will surely enable them to become major contributors in any technology-centered organization.

QUESTIONS

1. What are the bases for trade-offs between conflicting wants and needs of different customers with respect to the same product? How important is it to emphasize product quality when a new and unique product is launched?
2. Is it better to market a new product quickly and then upgrade the design later or to incorporate all design modifications or improvements before launching the product?
3. How can product development costs be minimized by entering the market late?
4. Customers' wants and needs are regionally different for products intended for global markets. How can a centralized, concurrent engineering team develop a product that will serve as the common "platform" for global markets?
5. ABC Company wishes to enter a new market arena on the basis of its strength in core technologies and financial staying power. However, the market arena in question is currently dominated by a major competitor with 80% of the market share, and a number of smaller competitors are each focused on small niche segments. How should ABC Company enter this market?
6. A company makes a range of products and sells to several large, loyal customers to achieve a healthy market share. A new competitor has emerged to offer equivalent products at much lower prices. What should the company do?
7. The company wants to develop a new product for a high-end consumer market. It is known that customers in this market are difficult to identify and are geographically dispersed. How should the company plan for product distribution and promotion?
8. The company wishes to sell its current product in a new market segment. At the same time, it wants to launch a new product in the existing market segment. How should the company handle the product promotion?

Appendices

Appendix 8.A: Product Concept Testing Program (Air Cleaners)

In 1976, Dr. C. M. Chang, developed a nonelectric particle-filtration method while working at Praxair, a Fortune 200 industrial company. This technology was effective in eliminating airborne submicron particles in airstreams without producing the ozone gas that is harmful to people's health. Product concepts were subsequently refined for air-cleaning products for residential markets. The impetus for pursuing these product concepts is the notion that harmful respirable dust particles are expected to increase in concentration over time in the ambient air due to combustion-related emissions from cars, trucks, power plants, and factories. Respirable dust particles trapped in human lungs are known to lead to asthma, cancer, and other diseases and discomfort. Elimination of such particulate pollution in residential environments without the presence of ozone as a harmful gaseous agent should be attractive to consumers.

Before embarking on the major investment required for creating this proposed product line, the company decided to conduct a product-testing program to assess the consumers' acceptance of the conceived product concepts and define additional product features that would satisfy consumers' needs to the maximum extent possible.

1. *Focus group meetings*: A commercial product concept-testing company was engaged to conduct a series of focus group meetings for the purpose of gauging customers' responses to the proposed product concepts.

   In preparation for the focus group meetings, 18 versions of the products were proposed. These product concepts covered the particles' and gaseous pollutants' removal at high-, medium-, and low-performance levels. Tentative product names were assigned. Fabrication costs and features of competitive products were defined. Product brochures were prepared.

   Three teams of customers were selected to form the focus groups. A product presentation was made to each focus group, including product price, pollutant removal performance, and availability. Questions asked by participating customers were answered.

   Each focus group was asked to freely deliberate among its members their likes and dislikes and the advantages and disadvantages of the products. The groups were told that the products were currently in beta-testing stages in another part of the country and would soon be available in their region. The key question then was whether the customers would buy such products for their own use if they became available within a few months. If not at the proposed price, at what price would they be willing to buy the product?

   All deliberations were video-recorded for subsequent analyses.
2. *Findings*: The key findings are as follows: Among high-efficiency filter products, consumers buy air cleaners primarily for medical reasons. Therefore, products that are equally efficient, but at a lower price are not necessarily attractive for two reasons: (1) a high price ensures the perception of superior product features, (2) there may be an insensitivity to price because of medical insurance coverage. An air-cleaner device at equal price, but with much higher particle-removal performance (e.g., one with 95% filtration versus another with 99.95% filtration) does not appear to be attractive because consumers cannot notice the performance difference without employing measurement devices.

   High-priced products with intermediate particle-removal efficiency are not readily accepted by consumers with medical problems. These products are priced too high for other consumers interested only in reducing the residential environmental dust.

   Products with low filtration efficiency and low price may appeal to the general public interested in having an adequate furnace filter at a price "worth the risk" for them. A throwaway filter of this type appears to be worth further consideration, provided that it would cost only $5 or less and could fit into most existing furnaces. Figure 8.A1 summarizes the four categories of air cleaners defined by the two product features of price and particle-removal efficiency.

   The capability to remove gaseous pollutants in residential air does not seem to appeal to consumers. Window add-ons and self-standing units do not seem to be attractive to them either. In other words, consumers do not understand the beneficial value of the product features of ozone-free generation and efficient control of

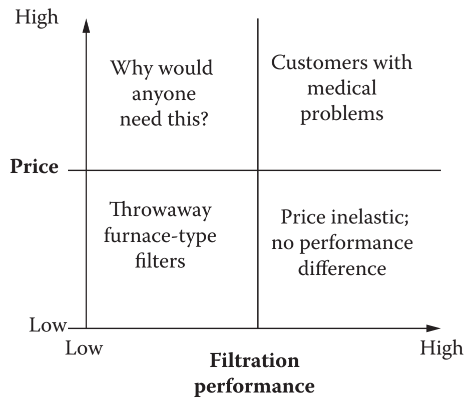

FIGURE 8.A1
Air cleaner categories.

submicron particles. It would take a major advertising effort to communicate the message and educate the masses.

However, countless consumers do purchase air-cleaning equipment without really knowing the difference in brands, because most electronic air cleaners have been purchased as part of a bigger package. Retailers' reputations for price and quality (e.g., Wal-Mart stores, Sears) have exerted a noticeable influence on consumers.

3. *Learning*: The key lesson learned from this product-testing program was that, if customers do not appreciate the value offered by a product, they will not buy it. In this case, the product developer did not fully appreciate the fact that, although it was scientifically evident at the time that inhaling submicron particles is detrimental to personal health, the majority of consumers do not appreciate the importance of such scientific facts and thus do not assign the proper importance to the product features offered. As indicated by Mello (2002), customer inputs are indeed useful.

Another lesson learned was that the timing of the products was also off. The air-cleaning products described were ahead of their time. In March 2002, studies published in *The Journal of American Medical Association* indicated that, for every 10 mg/m^3 increase in particle concentration in ambient air, there is an 8% increase in risk for lung cancer death and a 6% increase in death due to other lung- and heart-related diseases. Several major U.S. cities are known to have particle-pollution levels in excess of the U.S. Environment Protection Agency (EPA) standard of 15 mg/m^3. In the absence of similar studies and authentic sources of information, consumers will not understand the long-term benefits of such products as air cleaners.

In March 2003, Sharperimage.com advertised an Ionic Breeze air purifier at $349.95. This product was built on the basis of the principle of electrostatic precipitation. Flat-plate collectors, which are easily cleaned, are used to capture most submicron particles found in residential buildings.

In summary, the product concept-testing program that Dr. Chang's company used supported the notion that product concepts developed from technology may not be as commercially marketable as those derived from the perceived needs and wants of customers. The results of the program add evidence to the known reality that marketing is as important as technology innovation for a company to achieve commercial success.

Appendix 8.B: Consumer Survey and Market Research

To market consumer products, companies need to have a very detailed understanding of their customers, just as companies marketing industrial products also need to understand their customers, although to a much lesser extent.

When dealing with customers, the key questions typically concern what, how, where, when, why, and who.

For example, what functions does the product serve? What are the criteria to buy the product (price, color, size)? What is the value to the customer? What do they really want from the product (psychological, functional, and other benefits)?

How do customers compare products? How do customers decide to buy? How is the product used? How much are customers willing to pay for it? How much do they buy? How would the distribution mode and service center location affect the customers' buying decision?

Where is the purchase decision made (e.g., what is the customer's position in the company or household)? Where do they receive information? Where do they buy their products (retail store, mail order, department store, Internet, etc.)?

When do they buy it (weekly, monthly, special occasions)?

Why do they prefer one brand over the other (performance, price, convenience, packaging, colors, service, etc.)?

Who are the customers (age, background, sex, geographic location, members of social groups, etc.)? Who buys the competitor's products? Who does the buying (wife, husband, children, purchasing agent, engineers, others)? Who makes what decision for whom (decision-making units)?

To understand the behavior of consumers in making purchase decisions, companies focus on customers' habit in purchasing, consuming, and information gathering. Who buys, how often, where, how much, when, and at what price? Who consumes, on what occasions, how do they consume, in what quantities, where, when, and with what other products? What media do they use (industrial exhibits, trade journals, TV, newspaper, radio, Internet, etc.), and when?

It is also useful for companies to understand the process by which consumers make their purchase decisions. This process typically encompasses the steps of need arousal (problems to solve; discovery from neutral sources; Jones the bragging next-door neighbor; etc.), information search (online resources are now one click away), and evaluation and decision-making (comparative shopping, making trade-offs, brand versus product, and price versus quality and features).

Appendix 8.C: New Product Development

New product development has been extensively studied in the literature. Typically, companies follow a number of steps to develop new products: idea generation, idea screening, profitability analysis, product development, and commercialization.

To bring about new product ideas, companies use multiple sources. The internal sources include R&D and salespeople. The external sources include users initiated, competitors, industrial organizations, and product consulting firms. Innovation is the principal technique to identify valuable ideas by applying known principles to different processes or in unique configuration, thus producing unexpected benefits such as lower cost, smaller size, lighter weight, enhanced user convenience, better functionality, and so on.

Two examples of innovative products are noteworthy. The new Segway Human Transporter is a clever combination of known technology (battery, gyroscope, wheels, stick-enabled weight-based control) and constructed in a unique way to create unexpected benefits. Another example is Bandag, a major tire retreading company that provides specialty composite materials in its retreads in response to different road conditions and travel patterns. It developed an innovation by embedding a computer chip in the tire. This chip monitors tire performance, calculates wear and tear, and determines balance. It becomes a value-added service to truck-fleet managers who are then able to track the total cost of tire purchases better than before. Its value in use is derived through information and a tracking system that provides important savings due to added life to tires and minimized fuel costs.

Now Bandag's Tire Management Solution business unit offers quality service in the acquisition, maintenance, and recycling of tires to customers, allowing customers to focus on their own core business interests.

Product ideas must be screened with respect to criteria such as marketability, market size and growth rate, production capabilities, and profitability. Marketability refers to the extent to which the proposed product ideas are acceptable to the customers in the target segments. Factors affecting marketability include price, product quality, substitution products from competition, available distribution channels, and customer preferences. Market size and market growth rate must be at reasonable levels for the product ideas to be worth pursuing. Suitable production capabilities, such as raw materials, know-how, skilled labor, and equipment must be readily available. Finally, product ideas must have the potential for generating sufficient margins to justify the required investment expenditures.

In conducting profitability analysis for product ideas, several factors should be considered. The *demand factors* include users' needs, substitution products, price, advertising, segment size and growth rate, distribution, competition, and interaction with existing products. The *cost factors* are related to product cost, plant size, technology level, utilization of the plant, possible technological changes, and cost interdependency between existing and new products. The *profit factors* consist of product pricing, timing of profits (e.g., in three to five years), constraints on profits (due to plant capacity, financing limits, distribution requirements, management limits), governmental constraints (OSHA, trade, and environmental laws and regulations), and labor restrictions (availability of trained labor and seniority). The *decision factors* assess the profit levels, risks, uncertainty (as in estimating the risks in the market), and capital budgeting (investment, cost of capital, timing, and cash-flow pattern).

Once product ideas are deemed worth pursuing, some companies invoke the target-pricing approach (see Section 8.6.3) to determine the maximum CGS (target CGS) that would ensure commercialization and profitability of these product ideas.

A very detailed cost analysis follows for the requisite functions of *product design* (product attributes by a perceptual map, modular concepts, interchangeable components, subsystem compatibility, advanced materials, emerging technologies) and *fabrication and prototyping* (flexible production, fabrication technology, automated processes, quality control, supply chains, maintenance requirements). The full-scale product development work is to be authorized only if the target CGS will not be exceeded.

It is generally advisable for product development to be entrusted to a multifunctional team in which all major disciplines (such as marketing, sales, design, value engineering, production, distribution, procurement, customer service, and finance) are represented. Doing so will cut down the needs of subsequent design changes, improve the all-important time-to-market performance, and ensure a high probability of product acceptance in the marketplace.

One important area in which engineers should make significant contributions is cost reduction in the design and manufacturing of products. For example, developing innovative techniques to combine production steps, simplifying design, using lower-cost materials, and creating interchangeable parts for groups of products can all lower costs. Another area in which engineers can add value is the improvement of product reliability, serviceability, and maintainability.

For certain products, companies may elect to conduct a test marketing program. The purpose is to seek feedback from users regarding such variables as service quality, likes, dislikes, desired new product attributes, relative ranking of existing product features, and price levels that users are willing to pay. Also useful to collect are data related to sales results from the targeted segment, adequacy of selected distribution channels, effectiveness of the promotional message, and service quality. Such information will allow the company to augment its product attributes before launching a major product.

Product commercialization involves final preparations before launching the product. These preparations include specifying a *product name* that is easy to pronounce and distinguish; a *value package* with price, features, value, and product functionality; *product styling* (e.g., industrial design is important to car buyers); *production* (financing, labor and materials resources, technologies, and supply chains); *sales and marketing* (advertising, distribution, sales force training, and product brochures); and *service* (customer call centers, websites, maintenance and repair, and problem solving).

According to published survey results, the introduction of new products in different industries has resulted in quite different product failure rates (see Table 8.A1).

Figure 8.A2 presents the "1 in 60" product-development curve, in which 60 product ideas pursued initially whittle down to only one product that will become commercially

TABLE 8.A1

Product Failure Rate

Product Types	Failure Rate (%)
New industrial goods	20–40
New technology products	90
New packaged consumer goods	40–80
New food and drug items	50–80

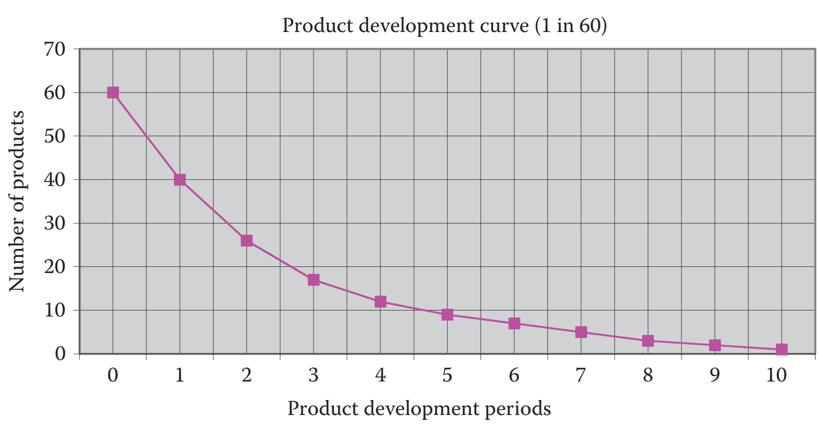

FIGURE 8.A2
Product development curve.

successful, if the company follows the traditional, sequential product development process. However, if a concurrent product development process is employed, the success rate will increase to 1 in 7.

There are a large number of reasons why products fail in the marketplace. The following list summarizes the principal reasons:

1. Lack of meaningful uniqueness in product features ("me-too" products)
2. Poor planning (no distribution, service, spare parts, inadequate advertising)
3. Wrong timing (economy, season)
4. Excessive optimism
5. Poor product performance (functional deficiency)
6. Product champion failure
7. Company politics
8. Unexpectedly high product cost

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Section III

Engineering Leadership in the New Millennium

Section III of this book addresses six major topics: (1) engineers as managers and leaders (Chapter 9), (2) creativity and innovation (Chapter 10), (3) ethics in engineering and the workplace (Chapter 11), (4) operational excellence (Chapter 12), (5) globalization (Chapter 13), and (6) engineering management in the new millennium (Chapter 14). These discussions provide additional building blocks to prepare science, technology, engineering, and math (STEM) professionals and managers to assume technology leadership positions and to meet the challenges of the new millennium.

STEM professionals and managers are known to possess a strong set of skills that enable them to do extraordinarily well in certain types of managerial work. However, some may also exhibit weaknesses that prevent them from becoming effective leaders in engineering organizations, or even from being able to survive as STEM professionals in industry. The expected norms of effective leaders are described. Steps are discussed that enable STEM professionals and managers to enhance their leadership qualities and attune themselves to a value-centered business acumen. Certain outlined steps should be of great value to those STEM professionals and managers who want to become better prepared to create new products and services, integrate technology into their organizations, and lead technology-based organizations.

Of particular importance for STEM professionals and managers to emphasize, when exercising leadership in the new millennium, is to contribute to the creation of strategic differentiation and operational excellence for their enterprises. Chapter 10 offers ways of generating novel ideas by using question-based prompts, and then develop differentiable and novel product/service packages to satisfy the customers' needs in the marketplace. Chapter 12 suggests a large number of proven industrial engineering productivity tools (e.g., Lean Six Sigma, value streaming mapping, failure mode, and effect analysis) and Internet-based productivity enablers (e.g., big data, analytics, and cloud computing) to facilitate communications, preserve company knowledge, cut cost, improve productivity, raise process efficiency, align supply chains and speed up time to market, and improve customer service for the enterprise.

Many tried-and-true rules are included that serve as suitable guidelines for STEM professionals and managers to becoming excellent leaders. Above all, they are expected to lead with a vision of how to apply company core competencies to create value, insights into how to capture opportunities offered by emerging technologies, and innovations in making products and services better, faster, and cheaper, so that they constantly improve customer satisfaction. The concepts of value addition, customer focus, mass customization, supply chains, and enterprise resources integration are also discussed.

Although STEM professionals and managers are known to rank high in trustworthiness and integrity (ahead of businessmen, bankers, certified public accountants, politicians, and lawyers), it is important for all STEM professionals and managers to remain vigilant in observing a code of ethics, along with taking seriously other topics related to ethics (see Table 11.2).

Globalization is further expanding the perspectives of STEM professionals and managers with respect to divergence in culture, business practices, and value. Globalization is a major business trend that will affect many enterprises in the future. STEM professionals and managers must become sensitized to the issues involved and prepare themselves to contribute to enterprises wishing to capture new business opportunities offered in the global markets. They also need to be aware of the potential effects of job migration due to globalization and prepare to meet such challenges. The major hurdle for STEM professionals and managers to overcome is the creation of global technical alliances that will enable them to take advantage of new technological and business opportunities.

STEM professionals and managers will face external challenges in the new millennium. What these specific challenges are, how engineering managers need to prepare to meet these challenges, and how to optimally make use of location-specific opportunities to create competitive advantages will be examined. Progressive companies will also change organizational structures, set up supply chains, expedite e-transformation, and apply advanced tools to serve customers better, cheaper, and faster. Globalization is also expected to constantly evolve. The United Nations has predicted that by 2020, three of the five biggest national economies will be located in Asia. There will certainly be winners and losers as businesses become more and more global. It is important for future engineering managers to explore prudent corporate strategies for engineering enterprises in the pursuit of globalization, while minimizing any detrimental impact on the environment and maintaining acceptable human rights and labor conditions.

How should STEM professionals and managers prepare themselves to add value in the new millennium? What are the success factors for engineering managers in the new century? What might be the social responsibilities of engineering managers in the decades ahead? These questions are addressed in the final chapter of the book. The new millennium will create ample opportunities for those who know how to properly prepare and equip themselves with the required skills, knowledge, savvy, and mind-set.

To foster the leadership roles of engineering managers, a six-dimensional model is proposed to emphasize its inside, outside, present, future, local, and global dimensions. The management challenges for STEM professionals and managers in these dimensions are discussed.

9

Engineers as Managers/Leaders

9.1 Introduction

Engineering managers lead teams, groups, units, or enterprises to generate products and services that are highly technical in nature. The importance of developing engineering managers is well recognized (Schermerhorn 2013). Many believe that the development of new engineering management talent is crucial to the survival and growth of their companies' businesses.

Technical talents are important prerequisites for becoming leaders, as most science, technology, engineering, and math (STEM) professionals do not readily accept superiors with weak technical credentials. For this reason, countless organizations choose only topflight engineers as candidates for development to become corporate managers.

Typically, engineers are well trained for certain managerial functions. They are known to have the following skills and attributes:

1. Thinking logically, methodically, and objectively while making unemotional decisions based on facts and data
2. Analyzing problems and defining technologically feasible solutions
3. Understanding what motivates other STEM professionals
4. Evaluating work with highly technological contents
5. Planning for the future, addressing the company's needs in technology, productivity, and cost-effectiveness
6. Discussing technical information with customers
7. Possessing technical expertise that supports high-quality decision-making

Statistics indicate that, whereas engineers are highly trained professionals, as a group, they play only a limited leadership role in U.S. industry and economy. Does the engineering mind-set represent a disadvantage for certain top-level managerial positions? Some people say there may be certain personal attributes, traits, and habits that tend to cause engineers to be poor managers. This chapter addresses some of these potential drawbacks (Younts 2006).

The first part of this chapter looks at the career path of a typical engineer, the factors affecting the promotion of engineers to managers, the factors causing engineers to fail as managers, and finally leaders and managers. The second part of the chapter discusses leadership styles, qualities, and attributes; leadership skills for the twenty-first century; unique contributions expected of engineering managers; and a career strategy for the new millennium. The chapter concludes with a *take-charge formula* to inspire engineers to be proactive in managing their own professional lives.

9.2 Career Path of a Typical Engineer

In any engineering organization, people accept different positions; some are classified as line positions, whereas others are staff positions. Holders of line positions perform various activities in order to produce and market products or services. Holders of staff positions provide advice, services, and support to the holders of line positions. A career path represents a planned progression to higher-level positions of responsibilities within or outside an organization, each of which may require a different set of business and technical skills.

9.2.1 The Engineer as Technical Contributor

At the beginning of an engineer's career, his or her job is mostly of a technical nature. Tasks performed include the application of engineering principles and know-how to technical problems in order to verify or predict a specific technical outcome. The engineer is expected to be able to *do things right* on the basis of his or her college education, which sometimes may be supplemented by on-the-job training.

Over time, the engineer may build a reputation for being particularly knowledgeable in one or more technical domains (e.g., component design, process development, quality control, or reliability analysis) and becomes recognized as an expert for others to consult with, should such a need arise. Because of his or her expertise, the engineer may be asked to serve as a technical contributor on teams involved in product development, technology-based projects, feasibility studies, and other such multidisciplinary group endeavors. Still, the work done by the engineer remains mostly technical in nature.

On a technical career path, the engineer is expected to accomplish technical work of high quality based on a solid understanding of engineering fundamentals, efficacious application of basic principles, and sound technical judgment. As seen by coworkers and managers alike, the engineer needs to be easy to work with. The engineer must exhibit strong motivation to learn and improve, in addition to a high degree of maturity and professionalism. In well-managed enterprises, the promotion of such engineers to the next level on the technical career ladder is usually assured.

It is highly advisable that engineers follow the 10 *Get Success* rules in managing their own careers:

1. *Get* connected to empower personal and business networks
2. *Embrace* own mistakes, and learn from them
3. *Take* the lead in teams to motivate and empower people
4. *Secure* diversified experience and knowledge
5. *Understand* self and do strengths, weaknesses, opportunities, and threats (SWOT) analysis
6. *Create* a personal strategic and operational plan

7. *Cultivate* an open mind toward things that are different and foreign
8. *Exemplify* own truthful and authentic self
9. *Strengthen* own practices, and adhere to ethics and integrity rules
10. *Sustain* best efforts all the time

Appendix 9.A lists a number of success factors affecting the career of an engineer in industry. Appendix 9.B itemizes some common reasons for career failures.

9.2.2 Midlevel Positions

After a couple of initial promotions on the technical career ladder, the engineer is now ready to assume higher-level responsibilities and will be asked to make an important choice between staying on the technical ladder and moving forward on the managerial career path.

The midlevel positions along the technical career path include such titles as senior engineer, consultant, engineering/development associate, and corporate fellow. On the managerial career path, these positions are equivalent to group leader, section engineer, manager, and director, respectively. Some companies may use slightly different titles, but the basic organizational design concept is that there are equivalent positions on these two career ladders leading up to director or fellow level.

On the technical career path, the engineer may assume greater responsibility for highly technical projects for which specific funds and people are allocated. The managerial responsibilities of an engineering or development associate or corporate fellow are limited. The expected key contribution is to add value through technological leadership related to new technology products and processes by invention and unique application of emerging technologies. A corporate fellow is usually recognized as a technical leader both inside and outside the company. Note that for numerous well-established companies, the technical ladder has a glass ceiling that tops out at the corporate fellow level. It is rare for companies to have another technical position at the corporate vice-presidential level.

More conventional is the managerial ladder, which requires the engineer to take on responsibilities that deal with nonengineering issues affecting the operation of the organization. As the individual progresses up this career ladder, the engineer spends less and less time on engineering/technology issues and tasks and more and more on managerial assignments. This career path continues beyond director to reach vice president of engineering/technology and chief technology officer (CTO). The expected key contribution is to add value by deciding on the correct technology-centered projects for the company to pursue, and by securing the needed resources to implement them.

Not everyone wants to become a manager. Typical incentives for some STEM professionals to favor moving into management include (1) gaining financial rewards; (2) exercising authority, responsibility, and leadership; (3) acquiring power, influence, status, and prestige; (4) receiving career advancement, achievement, and recognition; (5) combating fear of technological obsolescence; and (6) responding to a random circumstance—an opportunity that is suddenly available. These incentives need to be contrasted with certain drawbacks associated with being managers, such as increased workload, stress due to making decisions under uncertainty, difficulty in achieving work–family balance, burdens related to business travel, and so on. Whether a technical or managerial career ladder is suitable for an engineer is very much a personal choice, as there are advantages and disadvantages to both.

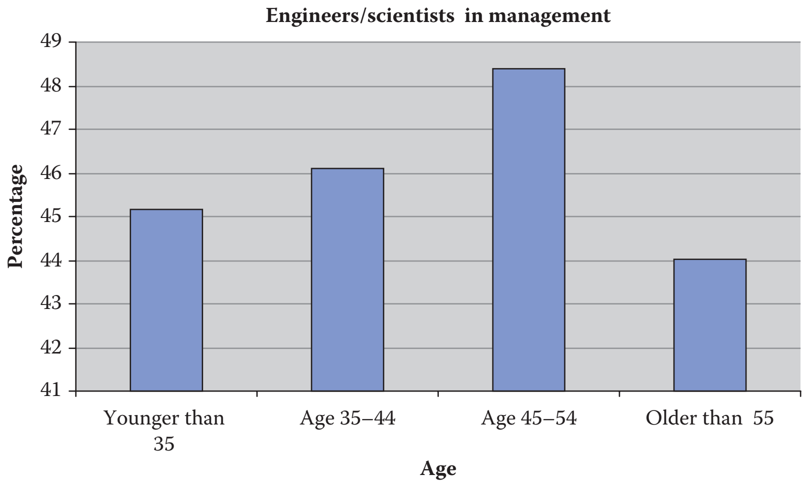

FIGURE 9.1
NSF Survey showing 48% of STEM professionals become managers. (From Surgent, J., *The US Science and Engineering Workforce: Recent, Current & Projected Employment, Wage and Unemployment*, CreateSpace Independent Publishing Platform, 2014.)

In a 2014 report, John Surgent of the National Science Foundation described the employment situation of U.S. engineers and scientists. Out of a total of 2,343,600 engineers and scientists, 46.1% held management and administrative positions. Figure 9.1 indicates that this percentage varies only slightly with age. Almost one out of two engineers or scientists has taken on managerial or administrative responsibilities.

Appendix 9.C includes some tips for first-time supervisors and managers to cope with their new responsibilities. At any of the previously described position levels, engineers will need to effectually collaborate with others, especially with their own superiors. Appendix 9.D offers some hints on how to properly manage one's own superiors.

9.2.3 Promotion to Next Level

Generally speaking, promotion along the technical career path is primarily based on company needs. A company may have five corporate fellows covering five different technology domains, but have only one CTO. If the individual's expertise serves as a core competency of the company, and the engineer's qualifications and the importance of responsibilities so justify, companies have been known to create new technical positions to accommodate such individuals (Benenour 2015; Asher 2014).

Promotion on the managerial ladder is subject to tough competition as the available opportunities carrying increasing executive-level responsibilities become more and more restricted. Exploring such opportunities outside the present employers may become a practical option.

Once in executive positions, engineering managers are expected to exert leadership in creating new visions and implementing technological strategies to foster business successes. Table 9.1 illustrates the change in work content of an engineering manager who advances from entry to middle management and executive-level positions.

Specifically, the CTO, who reports to the chief executive officer (CEO) and hopes to get important technological strategies accepted for implementation by the company, will need

TABLE 9.1

Changes in Work Contents

Emphasis	First-Line Supervisor (%)	Mid Manager (%)	Executive (%)
Technical	70	25	5
Managerial	25	50	25
Visionary	5	25	70

to work with and solicit support from peer officers: the chief information officer (CIO), chief financial officer (CFO), chief operating officer (COO), chief marketing officer (CMO), and chief knowledge officer (CKO). It takes leadership talents to be efficacious in such a collaborative setting.

9.3 Factors Affecting Promotion to Manager

Generally speaking, there are some basic prerequisites for engineers to receive promotions to the managerial ranks. These prerequisites will be discussed next (Humphrey 2013; Mohapatra 2014; Bhatawdekar and Bhatawdekar 2013).

The engineer must be able to master the duties and responsibilities of his or her current position, have the respect of his or her coworkers, and receive favorable recommendations from his or her superiors.

The candidate must have demonstrated his or her readiness to handle greater and more challenging responsibilities, as well as having gained the required skills and knowledge via courses, seminars, on-the-job training, professional activities, teamwork, volunteer work, tasks related to proposal development, feasibility studies, technology assessment, and other avenues. The candidate must possess the skills to manage time, and have the desire to seek leadership positions and opportunities to exercise power and manage people, spearhead change, and resolve conflicts.

Being competent and ready for promotion to managerial positions is a necessary, but not sufficient, condition for being promoted. The candidate's ambition, desires, and capabilities must also be a good match with the current and long-term needs of the company. Well-organized enterprises constantly need new managers and leaders because of the dynamics in the business environment, advancement of technology, competition in the marketplace, and the mobility of people.

Managerial competency may be classified according to the categories illustrated in Figure 9.2. Specifically, it is helpful for engineers who aspire to become managers to focus on the following general capabilities:

1. *Engineering management skills*: These skills include the engineering management functions of planning, organizing, leading, controlling, and the ability to work with people, and are built on having excellent communication skills.
2. *Power base formation*: Candidates must nurture the ability to build personal power by technical know-how, experience, and networking. Promoting and marketing one's own achievements are important, following the well-known saying, "Early to bed, early to rise, work like hell, and advertise!"

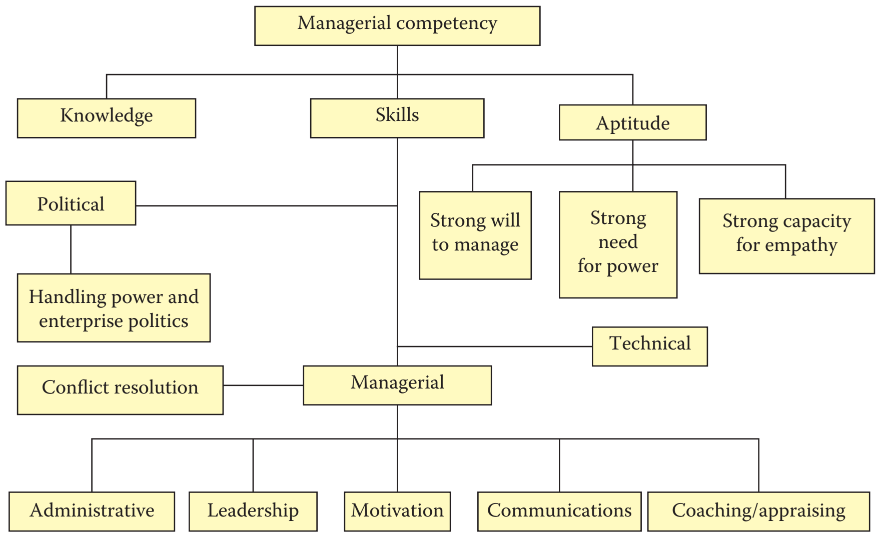

FIGURE 9.2
Managerial competency.

3. *Assertiveness*: Candidates should demonstrate the ability to become and remain assertive in exercising judgment and making decisions. They should be proficient in resolving conflicts and problems of a technical, political, conceptual, and people-centered nature.

One primary talent that defines managerial excellence is the ability to deliver tangible and measurable results regularly. Harvard Business School (2004) published the "The Results-Driven Manager" series comprising the following 21 concise, action-oriented guides

1. Motivating people for improved performance
2. Presentation to persuade and motivate
3. Face-to-face communication for clarity and impact
4. Winning negotiations that preserve relationships
5. Teams that click
6. Managing self for the career one wants
7. Becoming an effective leader
8. Managing change to reduce resistance
9. Taking control of own time
10. Dealing with difficult people
11. Getting people on board
12. Making smart decisions
13. Retaining the best people
14. Writing communications that inform and influence
15. Business etiquette

16. Connecting with customers
17. Creating breakthrough innovations
18. Hiring smart for competitive advantage
19. Managing performance for maximizing results
20. Executing strategy for business results
21. Managing knowledge to fuel growth

It should be useful for STEM professionals to review these capabilities and seek continuous improvements in all the requisite skills.

Example 9.1

According to Aucoin (2002), engineering managers must possess a set of skills that are not taught in a typical college engineering curriculum. These skills include the ability to (1) deal with ambiguity and uncertainty, (2) lead (teams, projects, and technological development), (3) take prudent risks, (4) delegate tasks to become increasingly effective, (5) be a team builder, (6) communicate, (7) initiate new projects, (8) negotiate to resolve conflicts, (9) network to form support groups, and (10) build alliances and partnerships.

How do you propose that an engineer acquire these skills?

Answer 9.1

To acquire the previously described skills, engineers could follow these steps:

1. Understand why each skill set is important, and verify its importance by talking with trusted partners (e.g., parents, close friends, relatives, professional acquaintances, and mentors). Other steps useful for enhancing understanding and building leadership skills are to
   a. Browse technical, business, and managerial publications (e.g., technical journals, *BusinessWeek*, *Fortune*, *Wall Street Journal*, and *Harvard Business Review*).
   b. Keep informed of new advancements in the field, such as business strategies, market expansion, technologies, innovations, customer relation management, enterprise integration systems, supply chain management, business models, lean manufacturing, and e-business.
   c. Absorb new concepts and practices, and become proficient in identifying *best practices*, *success factors*, and other benchmarks.
   d. Recognize new opportunities in technologies, business, and products potentially valuable to the organization.
2. Understand the metrics (standards) for measuring and monitoring progress made in acquiring these skill sets.
3. Conceive a plan for operation, including specific action steps and milestones.
4. Make a commitment to implement the plan by setting aside time and effort.
5. Take courses and training seminars, observe experienced managers and leaders in action, and ask experienced people to share their insight into acquiring the specific techniques needed to facilitate technical and managerial growth and to build and maintain skills. Training programs are available at professional societies. Some companies offer internal training services or subscribe to external courses. The American Management Association holds public training sessions. There are also some university-based training programs.
6. Proactively seek opportunities to practice the learned techniques. Volunteer for team assignments. Become an officer in a students' organization. Do

volunteer work in church, scouting organizations, charities, the United Way, the Rotary Club, or political groups. Spend time in professional societies or industrial committees. Join Toastermasters International to practice public-speaking skills.

9.4 Factors Causing Engineers to Fail as Managers

Certain articles address the factors that cause engineers to fail as managers. Engineers may be handicapped by a number of perceived shortcomings that do not allow them to become good managers. These perceived shortcomings are illustrated next.

Engineers tend to be straightforward, honest, and open, and have strong views based on verifiable facts and data. According to Broder (1992), some engineers (1) hate company politics (they tend to be technically intelligent, but sometimes politically amateurish); (2) do not build a personal network; (3) are uneasy trying to fit into an organizational culture because of strong beliefs, unique value systems, rigid principles, and inflexible attitudes; and (4) have an engineering mind-set that is rational, efficient, and introspective. They may see things as either right or wrong, and may not be willing or able to accept different shades of gray. For holders of midlevel and top-level managerial positions, this mind-set may confer disadvantages when attempting to resolve conflicts, handle disagreements, and foster alliances.

The technical training of engineers is based on equations, logic, experimental data, and mathematical analyses; this tends to make engineers see the world as orderly, certain, and black and white. The business environment in the real world causes some engineers to be uncomfortable with approximate or incomplete answers, since they have been trained well to recognize indeterminate problems and declare them unsolvable. They are not used to the idea of introducing additional assumptions and thus making such problems solvable. Some engineers hate problems with inaccurate or unknown factors and dislike planning with uncertainty (e.g., strategic planning). They may also want to avoid using intuitive knowledge. They prefer cognitive knowledge, which is based on facts and data, and thus they lack the ability and willingness to make tough decisions by using intuition and gut feelings.

Some engineers are too serious in their approach to professional life. They may be unable to say no and ask for help, allowing their personal ego and pride to get in the way. They may have the tendency to take mistakes personally, because they are afraid to be wrong.

Similarly, some engineers are conservative in nature. They may have a low tolerance for risks. Because of their tense personalities, they may not be comfortable taking risks to reach for higher levels of reward. Some graduates with a master's degree in business administration (MBA) are said to be "often wrong, but never in doubt"; they continue, despite often being wrong, to try new risky approaches until they reach their goals. Engineers are quite different in this respect. While having strong self-confidence in their own technical capabilities, many engineers do not like to take risks.

In fact, deciding to do something and actually doing so are two different things. There is the well-known riddle about *five frogs on a log* (Feldman 2001). "Five frogs are sitting on a log. Four decided to jump off. How many are left?" "Why, one frog of course," or "five frogs." Both are wrong. Even though four frogs decided to jump off, nothing is said about their having actually done so. Decision is not equal to action. Not taking action for fear of risks is typically viewed as a personal weakness.

Some engineers do not feel comfortable leaving their fields of technological strength when assuming managerial responsibilities. They tend to lean on technology as a safety net. From their viewpoint, technology is more readily controllable, and they are fearful of losing their sense of control. Some of them even have the uninformed notion that technology is the only thing worthy of respect, that it is valuable, intellectually pure, and deserving of their efforts. Their perspectives are limited, causing them not to recognize that other functions that may be technically less intensive, such as customer service, marketing, procurement, production, and supply chain management, can also contribute equal, or in some cases, more value to the organization than engineering and technology.

Because of their conservative nature, some engineers may be reactive in social settings and remain inflexible in dealing with a diversity of issues and people. Some of them may be readily argumentative and self-righteous when confronted with viewpoints radically different from their own. Over time, some of them may be perceived as suffering from a lack of human relations skills and the inability to become good team players.

One of the noted shortcomings of highly talented engineers is their lack of willingness to delegate. Some of them are not able to work through people and help others to succeed. They would prefer to ensure high quality by doing the projects or tasks themselves. Many are unwilling to develop subordinates for fear that one day the trainees may become technically more talented than themselves. Other engineers may have the tendency to apply self-imposed, ultrahigh standards in appraising employees. They have difficulty tolerating below par performance by teammates or coworkers. Still other engineers have the tendency to overmanage and overcontrol their subordinates.

Some engineers are unexpectedly promoted to managerial ranks because they performed well as technologists. Due to a lack of preparation on their part, these newly promoted engineers have either limited or no understanding of what managers are supposed to do—that is, to add value by efficiently applying resources to the right projects. They lack the preparation to do a manager's job. They are not aware of the fact that people problems require more time and attention than technical problems. Because of a lack of exposure to nontechnical but equally important issues, they have not acquired the background required to develop a well-rounded business sense.

Engineers may be specialists in narrow technical fields. As a consequence, they have narrow technical viewpoints and limited vision and perspectives beyond technologies. They are not prepared to deal with accounting, marketing, production, finance, and other corporate issues outside of technology.

Numerous engineers may suffer, to varying extents, from some of the shortcomings just cited. Engineers who aspire to become managers should carefully examine their strengths and weaknesses, and commit their efforts to making sure that all of these factors for failure are minimized over time.

9.5 Leaders and Managers

Companies need both leaders and managers. According to Tulsiani (2014), management focuses on (1) choosing goals and targets typically set by existing corporate strategies; (2) planning action steps to achieve the chosen goals; (3) allocating required resources;

(4) creating organizational structures; and (5) exercising control, measuring results, and correcting performance to ensure the attainment of goals. The primary duty of management is to keep the organization functioning properly. Management planning is deductive in nature, since it aims at creating orderly results.

Leadership, on the other hand, focuses on (1) setting a vision and direction for the future in response to changes imposed on the organization externally; (2) creating strategies to produce the changes needed to achieve the vision; (3) designing action steps to accomplish the strategic goals; (4) aligning people and forming coalitions; and (5) motivating and inspiring people to move in the right direction. The function of leadership is to produce change. Setting direction by leadership is inductive in nature, as it attempts to produce a new vision and new strategies. Vision is the picture of what the company will be in the long run with respect to its business portfolio, market position, technological prowess, and company culture.

The emphasis placed and the approach taken by managers differs from those of leaders. Table 9.2 summarizes such differences, based on published work (Breaux 2013; Olson 2014).

It is further believed that strong leadership with weak management is no better—and is sometimes actually worse—than the reverse. A competitive organization needs both strong leadership and strong management, and should use each to balance the other. Management is needed to ensure that complex organizations operate properly, including attaining incremental improvements. Leadership is needed to cope with changes that will be thrust upon the organization due to advancements in technology, changes in market environments, and competition at international level.

The transition from manager to leader has been the subject of a few studies (Conger 1992; Zenger and Folkman 2009). Engineers interested in becoming managers and leaders should also review the 78 questions raised by Bloomberg (2014), study the 12 principles delineated by Shallenberger (2014), and master the 6 competencies described by Pelus and Horth (2002). They may benefit from the lessons learned by other leaders (Krames 2004). Those who regard General Electric's Jack Welch as a leader to emulate have several resources to consult (Welch 2003; Krames 2005; Slater 2002).

Example 9.2

Every engineering manager has strengths and weaknesses. The key to continuous improvement is, of course, to identify one's own weaknesses and do something about them. How should an engineering manager study oneself and systematically discover opportunities for improvement?

Answer 9.2

Henry Mintzberg (2009), in his article "The Manager's Job: Folklore and Fact," proposed a large number of insightful questions for managerial self-study. These questions are worth studying. Examples of these questions are

1. Where do I get my information, and how? In what area(s) is my knowledge weakest, and how can I get others to provide me with the information I need?
2. What information do I disseminate? How may I get more information to others so that they can make better decisions?
3. Do I tend to act before information is in? Or do I wait so long for all the information that opportunities pass me by?
4. What pace of change am I asking my organization to tolerate? Is this change balanced?

TABLE 9.2

Differences between Managers and Leaders

Characteristics	Managers	Leaders
Focus	Do things the right way	Do the right thing
	Administration, problem solving	Direction setting
	Reconcile differences	Creativity and innovation
	Seek compromises	
	Maintain balance of power	
Emphasis	Rationality and control	Innovative approach
	Accept and maintain status quo	Challenge status quo
	Put out fires	Blaze new trails
Targets	Goals, resources, structures, people	Ideas
Orientation	Tasks, affairs	Risk taking
	Persistence	Imagination
	Short-term view	Long-term perspective
Success factors	Tough-mindedness	Perceptual capability
	Hard work	
	Tolerance	
	Goodwill	
	Analytical capability	
Points of inquiry	How and when	What and why
Preference	Order, harmony	Chaos, lack of structure
Aspiration	Classic good soldier	Own person
Favor	Routine	Unstructured
	Follow established procedure	
Approach with people	Using established rules	Intuitive and empathetic
Personality	Team player	Individualist
Relevance	Necessary	Essential
Thrust	Blend in	Stand out
	Bring about compromise	Lead changes
	Achieve win–win	
Mentality	"If it isn't broken, don't fix it"	"When it isn't broken, this may be the only time you can fix it."

Source: Adapted from Abraham Zaleznik, Managers and leaders: Are they different? HBR Classic Article # R0401G. *Harvard Business Review* (January 1, 2004).

5. Am I sufficiently well informed to pass judgment on subordinates' proposals? Do we have problems of coordination because subordinates already make too many decisions independently?
6. What is my vision for this organization? How firm are these plans?
7. How do my subordinates react to my managerial style? Do I find an appropriate balance between encouragement and pressure?
8. What kind of external relationships do I maintain, and how? Are there certain people I should get to know better?
9. Is there any system to my time scheduling, or am I just reacting to the pressure of the moment?

10. Do I overwork things? Do I need to take a break or to reduce the pace of my activity?
11. Am I too superficial in what I do? Should I decrease the amount of fragmentation and interruption in my work?
12. Do I spend too much time on current and tangible activities? Am I no longer able to concentrate on issues? Do key problems receive the attention they deserve?
13. Do I use different communication media appropriately (face to face, written, etc.)? Am I detached from the heart of my organization's activities?
14. How do I blend my personal rights and duties? How can I turn my obligations to my advantage?

9.6 Leadership Styles, Qualities, and Attributes

9.6.1 Leadership Styles

The consulting firm Hay Group conducted a survey on leadership styles with a sample of 3,871 executives, from a worldwide database of 20,000 executives. According to Goleman (2013), the following styles were identified by the survey as particularly useful for generating results: (1) authoritative ("come with me"), (2) affiliate ("people come first"), (3) democratic ("what do you think?"), and (4) coaching ("try this"). Goleman also advises that leaders should minimize the use of two additional styles, namely, (5) coercive ("do what I tell you") and (6) pacesetting ("do as I do now").

Effective leaders are said to switch constantly between the authoritative, affiliative, democratic, and coaching styles, depending on the situation at hand. The key concept here is flexibility. Those engineers who are weak in any of these four styles are advised to seek self-improvement.

Example 9.3

The NASA space shuttle *Columbia* broke up during its descent on February 1, 2003, killing all crew on board. Immediately after its launch, it was made known to NASA Mission Control Center that a piece of solid foam had broken off from the shuttle's external fuel tank during its ascent and smashed into its left wing at high speed. During *Columbia*'s 16-day space journey, NASA management dismissed the significance of this mishap and did nothing. Instead, NASA insisted that the incident was a routine affair, as foam pieces had broken off in a number of previous space flights. Furthermore, NASA overturned the requests of its lower-level engineers to obtain U.S. Department of Defense pictures of the wing that were photographed by military satellites. Low-level engineers e-mailed a query to their superiors about the possibility of getting the astronauts to take a spacewalk, which was safe and easy to do, to inspect the wing. That e-mail was never answered.

NASA management lost two precious opportunities to avert the disaster. Furthermore, *Columbia* could have had its mission extended by another three to four weeks, allowing the shuttle *Atlantis*, whose launch schedule could have been accelerated to February 10 (from its original launch date of March 1) to rendezvous and rescue the crew. The other option would have been for two *Columbia* spacewalkers to repair the damaged wing with heavy tools and metal scraps scavenged from the crew compartment.

The Columbia Accident Investigation Board (CAIB) conducted interviews, shot foam pieces experimentally at test wing targets, and analyzed a large volume of data. Its final report pointed clearly to a NASA management failure, attributable to several named managers.

What were the principal modes of management failure deemed responsible for the shuttle *Columbia* disaster?

Answer 9.3

The *Columbia* shuttle disaster was the result of several factors (Langewiesche 2003):

1. *Culture*: NASA claims that it is a *badgeless society*, meaning that it does not matter what title of position and responsibility is on one's name badge; everyone is equal when it comes to concern about shuttle safety. NASA has an open door and free communications policy.

   The opposite was true, according to Langewiesche. He found that many NASA employees were afraid to speak up. In fact, Langewiesche claims in his article that many employees feared that their position in the organization predetermined how they themselves were viewed, as well as how their opinion was welcomed or accepted by the higher-ups. Many employees felt NASA's leadership style to be coercive, not democratic.
2. *Overconfidence and personal arrogance*: The NASA managers had shown arrogance and insularity, while exhibiting a tough and domineering management style. Langewiesche says that the CAIB report singled out a specific NASA decision-maker as "intellectually arrogant and an abysmally failed manager." Moreover, Langewiesche claims that the NASA managers demonstrated imperious and self-convinced attitudes, suffered from a lack of curiosity, and believed in themselves blindly. It is not difficult to see and understand that, as NASA had completed over 100 successful space flights, managers could blithely accept the notion that there would be no fatal risk upon the foam breaking off at lift-off. Previously, when lift-off had created similar mishaps, there were no serious repercussions.

   Ultimately, it was conclusively substantiated by CAIB tests that the falling foam had punched a hole about 10 inches wide into the wing's leading edge. This hole allowed the hot gases of reentry to enter the shuttle compartment and burn it from the inside. Unfortunately, there was no other past experience upon which the higher-ups could base their decisions, although they perhaps should have erred on the cautious side, rather than the less costly side.
3. *Pressure to meet deadline*: The NASA administrator set stringent performance goals related to the International Space Station Project. The strict deadline for completing the *core*, of which *Columbia* was a part, was February 19, 2004. As a consequence, organizational and bureaucratic concerns weighed heavily on the managers' minds.

A combination of the foregoing three factors led the key managers to stubbornly believe that the foam strike was insignificant, and also led them to forego the opportunity to collect more data and hence fail to initiate emergency steps to save the crew. It was a colossal engineering management failure.

9.6.2 Emotional Intelligence

According to Goleman et al. (2013), all effective leaders have a high degree of emotional intelligence. There are five components of emotional intelligence: self-awareness, self-regulation, motivation, empathy, and social skills. Each of these components can be learned and enhanced by coaching, observation, training, and practice.

Engineering managers are advised to nurture these components of emotional intelligence so that they can lead effectually.

9.6.3 Inspirational Leadership Qualities

Leaders typically have vision, energy, authority, and strategic direction. However, leaders will not succeed if there are no followers. Followers are hard to find in these "empowered" times. Goffee and Jones (2006) point out that there are four specific qualities needed by leaders who want to be truly inspirational:

1. *Approachability and humanity*: It is a human quality to show personal humility and vulnerability. Doing so will demonstrate authenticity, promote trust building, enhance solidarity, and foster collaboration. Acknowledging one's own shortcomings opens up opportunities for improvement. However, the authors advise that the weaknesses shown should be tangential flaws (such as hardworking habits) only and not fatal ones or character-related issues.
2. *Tact*: The ability to know when and how to act based on intuition. Tact is a situation sensor that is capable of reading underlying currents, detecting subtle cues, and gauging unexpressed feelings. This quality is widespread among excellent business leaders. However, one needs to make sure that reality testing is done frequently with trustworthy friends or confidants, to avoid disasters due to one's own inability to evaluate faulty situations.
3. *Tough empathy*: This is the ability to establish a balance between respect for individuals and the task at hand, in order to impel leaders to take risks and to care about the people and the work they do. Leaders do well when they close the distance between themselves and their employees. Leaders must give employees what they need by helping, coaching, and participating in what they do.
4. *Uniqueness*: The ability to maximize the benefits derivable from the leader's own uniqueness (e.g., expertise, reputation, imagination, loyalty, dress style, physical appearance, handshake, and humor) and to use this separateness to motivate others to perform better.

Leaders need to be themselves, acquire more skills, and apply these four qualities to fit their own personality styles to successfully inspire others.

9.6.4 Leadership Attributes

Leaders are those who have special knowledge, are accessible, exhibit charisma (the natural ability to attract followers), and possess the authority to delegate. Table 9.3 contains a set of basic guidelines for engineering managers to lead.

Various research articles on leadership indicate that efficacious managers possess a set of common attributes. They have unquestionable character. Their creditability is high because of their technical skills, ethics, fairness, and moral standards. They master the functions of management, such as planning, organizing, leading, and controlling. They constantly perfect their skills in dealing with people, managing time, and controlling their own stress. They communicate effectually both in oral and written forms (Harrison

TABLE 9.3

Basic Guideline for Managers to Lead

1	Prepare oneself (e.g., study the rules, policies, and objectives of your organization)
2	Understand all jobs under one's direction
3	Be observant of things going on around oneself (e.g., managing by walking around)
4	Pay attention to details
5	Pose questions
6	Keep things in perspective (e.g., avoid being too close to the trees and unable to see the forest)
7	Be anticipatory of the future conditions.

and Mulhberg 2014). They have learned to listen well. They are full of energy and in good health. They are enthusiastic and positive about things and people. They are self-motivated, flexible, and independent. They take actions to influence events. They take prudent risks if needed (Tracy 2010). They have superior conceptual skills in reviewing data, solving problems, taking action, and planning strategically. They are both persistent and persuasive in achieving the goals they set out to achieve. Because of these attributes, they create good impressions and build confidence in others' minds. Effective leaders attract those who are willing to follow them.

In fact, these attributes are not dissimilar to the profile of top executives commonly noted in the business literature (see Table 9.4).

Managers and leaders have different mental orientations. These mental orientations make leaders as important as managers in adding value to their organizations. Leadership talents are defined as having a natural predisposition for recurring patterns of thoughts, feelings, and behaviors that can be applied productively. The Gallup Organization (www.gallup.com) has identified 20 key leadership talents by interviewing more than 40,000 leaders and top-tier managers over a period of 30 years (Fulmer and Wagner 1999). These 20 leadership talents are classified in the following four groups

TABLE 9.4

Profiles of Top Leaders

1	Are able to work with people
2	Possess social poise (self-assured and confident)
3	Are considerate of others
4	Are tactful and diplomatic
5	Practice self-control
6	Are able to analyze facts, to understand and solve problems
7	Are able to make decisions
8	Are able to maintain high standards
9	Are tolerant and patient
10	Are honest and objective
11	Are able to organize time and priorities
12	Are able to delegate
13	Are able to generate enthusiasm
14	Are able to be persuasive
15	Possess a great concern for communication

A. *Ability to provide direction*
   1. Vision: is able to build and project beneficial images
   2. Concept: is able to give the best explanation for most events
   3. Focus: is goal oriented

B. *Drive to execute—related to motivation*
   4. Ego driven: defines oneself as significant
   5. Competitive: has the desire to win
   6. Achiever: is energetic
   7. Courageous: relishes challenges
   8. Activator: is proactive

C. *Capacity to develop relationship with others*
   9. Relater: is able to build trust and be caring
   10. Developer: desires to help people grow
   11. Multirelater: has a wide circle of relationships
   12. Individuality perceiver: recognizes people's individuality
   13. Stimulator: is able to create good feelings in others
   14. Team leader: is able to get people to help each other

D. *Management system—related to management abilities*
   15. Performance oriented: is results-oriented
   16. Disciplined: is able to structure time and work environment
   17. Responsible and ethical: is able to take psychological ownership of one's own behavior
   18. Arranger: is able to coordinate people and their activities
   19. Operational: is able to administer systems that help people to be more effective
   20. Strategic thinker: is able to do what-if? thinking and create paths to future goals

It is obvious that a good leader must be a good manager, but a good manager may not be a good leader if he or she lacks some of the leadership talents indicated. In fact, all of them asymptotically converge into a finite set of common leadership attributes that all future engineering leaders should feel comfortable assimilating. Engineers who aspire to become leaders are encouraged to understand and display these attributes so that, over time, the leadership talents and attributes will become second nature to them.

Example 9.4

Highly talented technical professionals may have academic training (advanced degrees), experience (company tenure), professional credentials (technical committee activities, awards, business connections), and accomplishments (patents, publications, completion of major projects) superior to the engineering manager. They could be difficult to manage. What are some of their characteristics and working habits? What strategies are effective in managing them?

Answer 9.4

Highly talented technical professionals tend to have the following work-related preferences:

1. They favor individual assignments with clearly recognizable responsibility. They do not prefer teamwork, wherein individual contributions may be crowded out.
2. They tend to strive for perfection, as they view the technological output as a reflection of themselves.
3. Technical professionals typically become easily frustrated by unexpected changes in program priority or resource allocation strategies for approved action steps deemed essential to achieve the program objectives.
4. They hate management jargon.
5. They find happiness in technical work, without being constrained by other nontechnical concerns or the involvement of low-skilled people.
6. They are readily turned off by administrative details, restrictive policies and guidelines, poor quality decisions based on questionable data and assumptions, excessive reporting requirements, and overly tight management control.
7. These workers assign high value to independence, self-motivation, self-direction, and fairness.
8. They demonstrate a reserved attitude in social interactions.

Highly talented technical professionals may be managed by adopting the following strategies:

1. Decide on the objectives of technical programs or tasks, define the funding priority, understand the reasons for decisions, and secure the company's commitment to the chosen programs.
2. Assign technology programs and tasks to specific individuals by clearly communicating the objectives, budget constraints, expected results, and other details. Suggest specific ways to measure outcome.
3. Solicit comments from the individual technical professionals involved regarding project value, interest, readiness to perform tasks, and other issues that may have been of concern to them.
4. Invite the individual technical professionals to
   a. Outline specific technical methods to accomplish the program or task at hand.
   b. Produce an action plan and define budget requirements (accounting for man-hours, equipment, supplies, computation resources, outside resources, etc.).
   c. Specify preliminary milestones of when interim results are to be reported out (monthly, biweekly, etc.).
   d. Define deliverables.
5. Review and accept the plans. Authorize the individuals to commence programs and tasks.
6. Be available for any unexpected problems encountered by the individuals pursuing these assignments (e.g., practicing the concept of management by exception). Must be helpful and leave sufficient room for independent work by the individuals.
7. Acknowledge receipt of the final report after it is submitted. Read the report, review results with individuals, discuss lessons learned, and invite comments on any work extension needed or desired and on how to enhance the management aspects of the program.

8. Evaluate the work performed in terms of its expected value to the organization and offer feedback, including any responses from top management and other parties affected by the accomplished programs or tasks.
9. Praise the individuals appropriately whenever good work is done, by, for example, practicing the concept of motivation by positive reinforcement and recognition. Offer improvement suggestions if performance is to be improved.
10. Seek and arrange opportunities for the individuals to make prepared presentations on technical programs and tasks during review meetings with upper management groups.
11. Document tasks and evaluations (including specific contributions made and their significance to the company) to be in a position to provide an instant report to upper management, if required, and to form a basis for the annual appraisals of the individuals involved.

9.7 Leadership Skills for the Twenty-First Century

The twenty-first century marketplace is characterized by a fast pace and stiff competition, low patience and compliance with authority, close relationships with customers, and a brisk speed to market. Rapid changes are expected due to global interactions, dynamic environments, technological advances, and population diversity. Jack Welch, a former CEO of General Electric, said, "When the rate of change on the outside exceeds the rate of change on the inside, the end is in sight" (Krames 2005). Business success in the twenty-first century requires global connectivity, innovative discoveries centered on customer satisfaction, enhanced performance of people and technologies, alternative organizational frameworks, real-time responses, and enduring self-examination.

In the new century, leaders need a new set of skills to help exercise their leaderships. These skills include

1. Leading with a strategic focus and vision. Advancing and articulating a value proposition that represents a proposed model to create value to companies' stakeholders.
2. Managing multiple points of view simultaneously, such as those from customers, suppliers, shareholders, and employees. Remaining flexible and adaptable in dealing with technology, working with people, and forming business networks. Being capable of negotiating for solutions that are acceptable to parties involved.
3. Keeping high-level goals in sight, while managing and tracking day-to-day success. Keeping the spirit of the enterprise alive.
4. Fostering productive changes. The *boiled frog syndrome* is explained as follows: If you put a frog in a pan full of cold water and slowly turn up the heat, the frog will boil to death rather than jump out. If you drop a frog in a pan full of boiling water, however, it will jump out immediately. The moral of the story is that, if people do not sense a significant need to change, they may not get out of their comfort zones and change what they are doing. Usually, effective leaders are needed to convince people of the need to change.
5. Being inspirational, technologically savvy, entrepreneurial, and devoted to customers' needs.

6. Investing in a business model that guides employees' decision-making at all levels.
7. Devising and maintaining transformational knowledge systems.
8. Accessing relevant information rapidly in light of the explosion of available knowledge bases.
9. Understanding how global business practices have evolved.
10. Learning quickly while not relying on what is already known or understood.

Engineering managers need to have business savvy in order to lead in the twenty-first century. The combination of technological know-how and business savvy is powerful. The following guidelines may help engineering managers to acquire the needed business acumen: (1) Become well versed in the business issues faced by the company. This includes a thorough understanding of the corporate vision; the company's priorities, strengths, and weaknesses; the current market position; business processes; and engineering and technology factors driving shareholder value. In other words, constantly sharpen one's own business sense. (2) Know how to define proper metrics to measure a company's financial and cost performance. These include income statements, balance sheets, fund flow statements, and various ratio analyses. (3) Recognize that technology is to be viewed as a tool to achieve business success. That is, technology can make a business become more profitable and productive. Delivering value to customers remains the key to achieving business success. (4) Be able to recommend suitable emerging technologies to enhance shareholder value and to mobilize resources (including the engagement of networked partners) to turn these visionary goals into reality. (5) Be persistent in pursuing a vision, which is based on legacy and not on activity. Winston Churchill said, "The further backward you look, the further forward you can see" (Jackson 2004).

Example 9.5

Negotiating for agreements between employees, departments, suppliers, production partners, and networked distributors is part of a manager's job. Explain the guidelines for conducting efficacious negotiations.

Answer 9.5

There are numerous excellent books on negotiations (Fisher et al. 2011; Thompson 2011). Next, a summary of the key guidelines is listed for effective negotiation:

1. Focus on the merits by attacking the underlying issues involved, not the opponent or their position.
2. Look for creative solutions with which both parties can win.
3. Prepare yourself well beforehand. The prenegotiation preparation centers on standards that suggest the best deal and available alternatives.

   Sample questions related to preparation include: (1) How much are the other vendors selling that brass dish for? (2) What do your competitors charge for the service you are offering? (3) How much does a person with your experience get paid? (4) What is your best alternative to a negotiated agreement?
4. Raise questions to find out what your opponent really wants, and prepare clever arguments to support what you need.

   The *parable of the orange* says that two parties each want an orange and agree finally to split it in half. But it turns out that one side simply wanted the juice and the other side wanted the rind. If only they had worked together to solve

TABLE 9.5

Examples of Exchanges

Question	Answer
What is the most you would pay if you had to?	If you think that no agreement between us is possible, perhaps we should get someone trustworthy to arbitrate.
If your company agrees to be merged into ours, how many of your employees can be laid off to achieve economies of scale?	Which of your branch offices would you be keeping and which would you close?

the problem, each side could have gotten what it wanted. According to Walker (2003), situations similar to that in the parable of the orange pop up a lot.

Be prepared to ask questions pertaining to who, where, what, why, and how, as they tend to drive your opponent to disclose more information than the yes–no questions (e.g., "How did you arrive at that figure?"). Posing questions to your opponent is also useful for fending off your opponent's questions to you that you may not be prepared to answer. Table 9.5 presents some examples of such exchanges.

5. Listen intently, as the power rests with the listeners. Silence is one of the best weapons available to negotiators. Keeping silent will force the opponent to talk more and, as a consequence, to revise his or her position and reveal useful information in the process.
6. Make use of the principle of consistency (Long 2013). The *principle of consistency* is that people have the need to appear reasonable. This can be used skillfully to make your opponent feel that, to appear reasonable, he or she needs to use your standards that have been determined during your prenegotiation preparations. The more authoritative your standards seem, the better. An example of such a standard is the price charged for similar goods by the competitors of your opponent.
7. Let your opponent make the opening offer. Studies indicate that people often underestimate their own strengths and exaggerate those of their rivals.
8. Take a psychological test (e.g., the Thomas–Kilmann Conflict Mode Instrument) to understand your own style, be it *competitor* or *collaborator*. Taking such a test will help define any aspects of your negotiation style that should be fine-tuned.
9. Be aware of some tactics employed by your opponents. Some may flinch at your proposals on purpose. Others, with the intent to mislead, may exaggerate things they do not really care about. At the close of negotiation, some opponents may say something like, "Wow, you did a fantastic job negotiating that. You were brilliant." Yet others may take advantage of the *Columbo effect* by lulling you into underestimating them and becoming overconfident.
10. Practice makes perfect. Effectual negotiation is 10% technique and 90% attitude. Attitude is affected by realism, intelligence, and self-respect.

9.8 Unique Contributions Expected of Engineering Managers

In what way is the technical background of a manager important to today's executives? If an engineering manager does only what a typical nontechnical manager does, then the engineering manager does not earn his or her keep. Specifically, what can a technically trained manager do that a nontechnical manager cannot? Technological intuition and innovation are the areas that engineering managers can and should excel at (Betz 2011; Tucker 2008).

How are innovation and creativity measured? A commonly accepted performance yardstick is counting the number of patents a company receives. More recently, a new measure was proposed to assess the relative value of patents. If a new patent application cites certain prior art patents as background on which the new patent is based, then the prior art patents are regarded as *forward citations*. The value of a patent is said to be directly proportional to its number of forward citations, as more forward citations indicate a broader significance.

For the moment, let us stay with the patent number as a measure of innovation and creativity (Durham 2013). According to statistics published by the U.S. Patent and Trademark Office, only 6 U.S. companies were among the top 12 global companies receiving the most U.S. patents in 2014.

Engineering managers are capable of adding value to their employers in diverse ways. The following are additional broad-based contributions expected of engineering managers:

1. Use of specific new technologies in product design—novel use of materials, parts, subassemblies, production technologies, and other components.
2. Application of web-based technologies to e-transform the enterprise in order to achieve refinements in process efficiency, quality, speed, or customer satisfaction.
3. Selection of enterprise integration tools for expediting business information collection, transmission, and processing in order to realize speed, cost, and quality advantages.
4. Alignment of networking partners to secure competitive advantages in supply chains, production systems, and customer service.
5. Looking out for new technology-based tools that could facilitate serving customers better, cheaper, and faster, with products that have a greater degree of customization.
6. Employment of new technologies and innovations to add value to stakeholders other than customers (e.g., investors, employees, suppliers, and the communities in which the companies operate).
7. Scanning literature to constantly learn the best practices of technology management in the industry.

Besides the aspect of relative competitiveness, the new era is full of challenges due to rapid advancement in technologies, internet-based communications techniques, and globalization. The need for technological leadership is becoming increasingly pronounced (Hamel 2003). The areas in which engineering managers are expected to make significant contributions are discussed in the next sections.

9.8.1 Technologists as Gatekeepers

A gatekeeper's primary job is to inspect and authorize the entry of people or materials into a gated organization. Technically capable people are usually entrusted with this important corporate activity to systematically scout, evaluate, and introduce new technologies for use by the enterprise (Maddock et al. 2011).

Engineering managers are in the best position to mobilize capable technologists who understand the new or emerging technologies available in the marketplace and their relevant value to a company's products, operations, and services. Capable STEM professionals can also bring in and selectively apply new technologies.

9.8.2 Technological Intuition

It is widely recognized in the literature that nontechnical managers do not have enough background to develop intuitions about which of the possible technologies now on the horizon are likely to advance further and which are likely to be discarded. Nontechnical managers cannot judge the merits of revolutionary changes in technology; this is known as a *factor of ignorance*. They have no choice but to procrastinate and wait for it to become clear which technology is the best; this is known as a *factor of risk aversion*. By the time the answer is clear, competitors may already have a two- to three-year lead in understanding and employing these new technologies. Thus, the nontechnical managers are not likely to exert excellent technological leadership.

This is also evident in diverse technical start-up companies, which, by the way, are typically headed by technically talented people. These talented entrepreneurs are able to invent new technology to serve as the basis for a new business. Eventually, some of these start-up companies might be acquired by big companies, which have the financial power to advance these technologies further.

Technological intuition is most needed in the strategic planning process conducted by a company. Hence, technologically talented managers have an important role to play here.

9.8.3 Technological Innovations

Another area of technological leadership expected of engineering managers is in the management of technological innovation (Kumar 2012; White and Wright 2003; Dundon 2002). Technological innovation is the process by which technological ideas are generated, strengthened, and transformed into new products, processes, and services that are used to establish a marketplace advantage and foster company profitability. The following statistics were published by Pearce and Robinson (2012):

1. Out of 58 initial product ideas, only 12 survive business analysis screening for compatibility with the company's mission and long-term objectives. This step uses 8% of the total development time.
2. Only 7 of the 12 ideas remain after an evaluation of their potential. This step uses 9% of the total development time.
3. Three of the seven remaining ideas survive after development work is completed. This step uses 41% of the total development time.
4. Only two of the original ideas remain past the pilot- and field-testing involved in the commercialization step, which uses 19% of the total development time.
5. Eventually, only one idea results in a commercially successful product. This step uses 23% of the total development time.

Within the product development process (see Figure 9.3), the most time-consuming and resource-intensive steps involve development and testing. Engineering managers

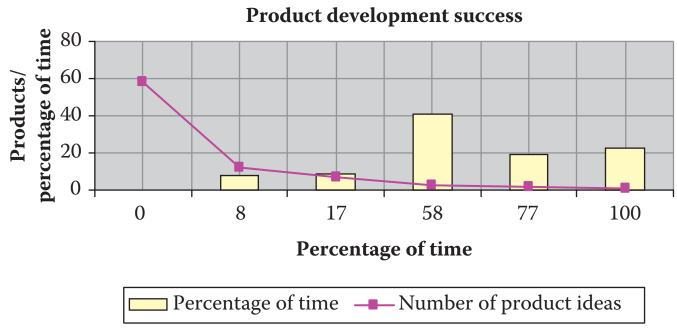

FIGURE 9.3
Product development process.

can make significant contributions to shorten development time and reduce costs while ensuring technical quality.

In heading up concurrent engineering teams in product development, engineering managers can excel by

- Asking pertinent technological questions
- Applying their interdisciplinary background to set technological priorities
- Incorporating new technologies to achieve competitive advantages and to satisfy customers' needs

Exerting strong technological leadership is where technically trained managers must shine. This is the uniquely attractive niche for engineering managers. Engineers do not have serious competition from nontechnical majors here, as it is relatively easy for engineers to learn how to manage, but not so easy for nontechnical managers to learn engineering. However, those engineering managers who cannot exercise technological leadership will be no better than nontechnical managers as far as the value added to their companies is concerned.

Innovation requires knowledge, ingenuity, and predisposition. Innovation cannot succeed without hard work. Purposeful work demands diligence, persistence, and commitment. Innovations need to be built on the company's strengths and core technologies. They should focus on opportunities that are *temperamentally fit*—that is, exciting and attractive to the innovators—inspiring them to do the required hard work. In addition, innovation must be market driven and focused on customers.

Engineering managers can benefit from taking a systematic approach to enhance individual innovation. Such an approach could include

1. Analyzing innovative opportunities systematically, focusing on (a) the unexpected successes or failures of the company and its competitors, (b) incongruities in processes (production, distribution, and customer behavior), (c) process needs, (d) changes in industry and market structures, (e) changes in demographics, (f) changes in meaning and perception, and (g) new knowledge.
2. Being observant (asking, looking, and listening). The types of questions to pose may include: (a) Which engineering processes or technologies from the past should be kept because they have future value? (b) What past engineering and

technological practices should be modified to be more relevant? (c) What activities should be eliminated because they have no future value? (d) What needs to be performed to ensure future success?

3. Recognizing that innovations must be simple and focused, application-specific to the present marketplace, and pinpointed on satisfying a need and producing an end result useful to the customers. It is not wise to innovate for the distant future markets, which may or may not materialize.
4. Starting small scale and aiming at producing a series of small, but useful incremental values. Focusing on areas for which knowledge and expertise are available.

It is equally important for engineering managers to exercise leadership in fostering corporate innovations. Managing group innovation is closely linked to managing group creativity. Implementing some well-established techniques, such as those enumerated in the following list, may enhance the creativity of groups.

1. *Brainstorming (for groups of 6–12 people)*: Many important corporate business or engineering issues may be cast in the form of problems. Examples of such issues include product design simplification, product or component cost reduction, and improvement of operations.

   By using brainstorming techniques, the leader defines a specific problem and requests each participant in the group to take a turn proposing possible solutions. No criticisms are allowed during these exchanges in order not to impede the free flow of ideas. After all of the ideas are generated and recorded, the group then carefully evaluates each solution and jointly defines the best solution to the problem at hand.

   As elucidated in Chapter 100, a new thinking methodology, *DeepThink*, suggests to engage teams, comprising of members with diversified background and experience, to exhaustively apply questions as prompts, in order to think deeper and generate ideas of increasing novelty in a multiple-round brainstorming environment. Initial outcomes of applying DeepThink have been positive.
2. *Nominal group technique (small groups)*: The leader defines a specific problem. Each member is encouraged to generate as many written solutions as possible during the group meeting. Each member is then invited to present his or her solution and to elucidate the relevant rationale behind the proposed solution. No criticism is allowed.

   After all of the proposed solutions are presented and recorded, each solution is thoroughly discussed, evaluated, and criticized. The participants are then requested to anonymously rank all of the solutions in writing. The final results are presented to management for action.
3. *Delphi technique (for identifying future trends)*: The leader defines a specific problem and a set of questions and sends them to a panel of geographically dispersed domain experts who do not have contact with one another. Each expert then answers the questions individually and anonymously. A summary of all of the answers is documented by the leader and sent back to the experts. By reviewing the comments and the possible criticisms, the experts, again anonymously, modify their original answers. No one knows who proposed or criticized what specific solutions. The focus is on the merits of the ideas, not on the personality of

those who advanced the ideas. The leader again prepares a summary and returns it to the experts, offering additional explanations and justifications. In the end, every solution is justified. Each time the experts respond to a summary, it is called a *wave*. After the third wave, a summary is prepared and the leader makes a forecast. This method is time-consuming, but it is particularly useful for predicting the future course that a company may take in technology and business.

Engineering managers ought to be well versed in many of these techniques to manage and promote creativity and innovation from both individuals and groups.

9.9 Career Strategies for the Twenty-First Century

Today's leaders adopt specific guidelines in managing their own careers (Wanjumbi 2015; Green 2013). Among many such guidelines published in the literature on career management, the eight specific guidelines offered by Kacena (2002) are particularly comprehensive and insightful (see Table 9.6). Fernandez (1999) offers a slightly different set of career strategies (see Table 9.7).

A set of new career strategies was recently offered to STEM professionals by Chang (2016). They include

1. Join the promotable ranks (prepare to be ready)
2. Acquire T-shaped competences (acquire a broad-based background and work experience)
3. Network to become visible to decision-makers and gain support of key people (manage own brand)

TABLE 9.6

Eight Specific Guidelines

1	Think, speak, act, and walk like an entrepreneur. Adopt an entrepreneurial mind-set, as if your own investment is involved. Accept the notion that jobs exist so that problems can be solved.
2	Make chaos a friend. Embrace change as an opportunity for growth. The mantra for today's career advancement is "eager to stay, yet ready to leave."
3	Don't be afraid to break the rules. Attempt to be a visionary, as innovation is possible only in cultures that tolerate mistakes. Be detail oriented.
4	Know your own strengths and weaknesses. Set high standards for yourself and affiliates. Be very competitive. Market yourself. Express commitment, passion, and excitement about your own work.
5	Be nonlinear. Radical career shifts will become commonplace. Companies are ignoring specialization in favor of adaptability, cross-functionality, people skills, and a rock-solid customer focus. Follow the new paradigm that anyone who does not know how to do something must learn or partner with someone who does know.
6	Maintain balance. Set your own priorities with respect to health, family, and business—in that order—and have fun. "Earn a living, make a life."
7	Stay connected. Building alliances by networking is essential. Establish reciprocal relationships with colleagues, clients, customers, and competitors. Seek to be helpful and supportive so that they become resources for ideas, skills, and knowledge.
8	Always keep your options open. Keep abreast of the market, nurture skills that are marketable, stay professionally active, and avoid becoming complacent.

TABLE 9.7

Fernandex Guidelines

1	Balance your priorities between your job, personal interests, family, and the community. This is the key to having a full and meaningful life.
2	Cultivate a broad business background through education, diversified work experience, and success skills. Ranked most important among success skills are integrity and persistence. Persistence means unwillingness to accept defeat.
3	Learn leadership from proven leaders. Observe successful people and learn from their behavior.
4	Learn what the company and industry are really about. Understand the company values, aspirations, brand character, market position, organizational structure and culture, and qualities of people.
5	Make an impact. Strive to contribute from the basis of knowledge and attitude. Ask how the world would be different and just a bit better because of your efforts.

4. Obtain requisite skills for the next level of promotion and beyond (know what is needed)
5. Avoid career errors (learn from others' mistakes)
6. Practice global leadership skills (be proficient in specific leadership skills)
7. Innovate to derive strategic differentiation and operational excellence (focus on value creation)

Engineering managers are advised to refine their own career strategies constantly by using the aforementioned inputs as general guidelines.

9.10 Take-Charge Formula

It is generally recommended that everyone must strive to become exceptional and to *take charge* of underutilized potential:

T: Time should be taken to reflect on your strengths and weaknesses, as well as to do something about the weaknesses.

A: Attitude must be fostered and modified as needed.

K: Knowledge must be updated to keep yourself marketable.

E: Empathy and consideration in caring for others' feelings should be strived for.

C: Communication must be constantly improved and perfected.

H: Health and humor must be diligently nurtured.

A: Appearance must be properly maintained.

R: Respect yourself and others and live one day at a time—enjoy life; why simply wait?

G: Goals should be set for yourself and your family by, for example, creating a five-year plan.

E: Empower the possibilities by finding ways to delegate, assist, entrust, and praise others, and by being generous and giving.

9.11 Conclusion

Many "rules of thumb" are derived from experience. They are common sense heuristics that are all reasonable and intuitively correct.

Knowing what is needed to become (a) an effective engineer, (b) a good engineering manager, or (c) an excellent engineering leader is a very good start. The next step is to learn the skills and capabilities to shape one's own attitudes, and to acquire the attributes needed to become an effectual engineer, good engineering manager, or excellent engineering leader. The third step is to lead and contribute in creating competitive advantages in strategic differentiations and operational excellence for the enterprise.

To be successful, one must practice, practice, and practice until the preferred behavior becomes second nature.

QUESTIONS

1. How can engineering managers make the best use of tools such as the Myers–Briggs Type Indicator (MBTI) to assist in selecting project leaders or assigning employees to teams to ensure the likelihood of avoiding personality conflicts that could otherwise hinder team success?
2. Engineering managers may be called on to resolve conflicts between employees, departments, vendors, and business partners, as well as to handle customer complaints. What are the recommended guidelines for handling complaints? Please elaborate.
3. Hoffman (1989) believes that a management education program should have three elements:
    a. *Behavioral*: People skills, motivation, team building, communication, and delegation
    b. *Cognitive*: Production, marketing, finance, and control
    c. *Environmental*: Markets, competition, customers, political, social, and economical environment in which the organization operates

    The importance of the first two elements should be self-evident. Explain why the third element, environmental, is important.
4. How is engineering management different from management in general?
5. How does a manager or leader become a good superior? What should the superior do and not do?
6. Does the job of managing a high-technology function (e.g., an engineering design department) differ from that of managing a low-technology function (e.g., a hotel)? Explain the specific details of the jobs.
7. What rules and principles can guide managers to have successful people management skills?
8. There are so-called unwritten laws of engineering that recommend acceptable conduct and behavior for engineers in industry. How important are these unwritten laws to individual engineers, and where can these laws be located?

9. Some engineers and managers are known to have more difficulties in interpersonal relations than others. These difficulties may arise due to personality, chemistry, value system, priority, tolerance, competition, and other such factors. How can they improve their interpersonal skills?
10. In your opinion, what are the characteristics common to many future engineering leaders? Please explain.

Appendices

Appendix 9.A: Ten Factors for Survival and Success in Industry (Alexander and Watson 2013)

To be successful in corporate America, one needs to pay attention to the following common sense success factors:

1. *Excellent performance*: Make sure that all assignments are performed well, as "You are only as good as your last performance." Pay attention to ensure that both the performance and its impact are properly recorded and made known to the people in the organization who might affect your career growth. Self-promote as needed.
2. *Personality*: Project a mature, easy to work with, positive, reasonable, and flexible personality. How one acts and behaves is important.
3. *Communication skills*: Of all aspects of communication, the written form is the most difficult to master. Check the writing advice offered by Hick (2013), with respect to readability, correctness, appropriateness, and thought. Consult the book by Strunk (2015), with respect to style.
4. *Technical skills and ability*: Keep your individual capabilities (e.g., analysis, design, integration, product development, and software tools application) current and marketable.
5. *Human relations skills*: Constantly review ways of interacting with people and make sure that you are creating and maintaining acceptable working relationships. Avoid being labeled as "not able to work well with other people."
6. *Significant work experience and assignments*: Seek diversified business and engineering exposure and high-impact assignments to build up your experience portfolio. Doing so will increase your ability to add value to the organization.
7. *Self-control*: Improve your ability to stay cool and withstand pressure and stress by, for example, taking courses in leadership training. According to a *CNN News* report in 2001, a British military training camp was offering training services to business executives, subjecting the executives to a high-pressure artificial military environment to toughen them up for handling the real-world business environment.
8. *Personal appearance*: Follow the example of superiors to fit yourself into the corporate image. *Dress for success*.

9. *Ability to make tough business decisions*: Take careful risks when needed. Anyone can make the easy plays, but only great people make the tough plays.
10. *Health and energy level*: Take care of your health and maintain a high level of physical vitality.

Appendix 9.B: Seven Most Common Reasons for Career Failures

Some engineers fail in their careers for one reason or another. Listed next are seven common reasons for career failure; these are relevant to technologists as well as managers.

1. *Poor interpersonal skills*: A lack of interpersonal skills is the single biggest reason for career failure. Few people are fired or asked to resign due to deficiencies in their technical capabilities. As a measure of social intelligence, interpersonal skills are important to achieve success in any organization. One needs to be sensitive to the feelings of others, able to listen and understand the subtext in communication, give and take criticism well, strive to build team support, and be emotionally stable.
2. *Wrong fit*: From time to time, a person may find it hard to adapt his or her abilities, styles, personalities, and values to the culture and business practices of the workplace. The workplace may assume a cultural norm that is unfamiliar to some individuals. It is well known that rigidly layered corporations operate differently from dynamic partnerships or entrepreneurial start-ups. The individual's core value system, with priorities, profit motives, and social or environmental preferences may not be fully compatible with those of his or her coworkers on the job. In addition, the chemistry among coworkers within a unit, department, or company could also be a source of conflict. Often, the management style of the superior is difficult for the individual to adapt to. In cases of such a wrong fit, the best strategy for the individual is to move on.
3. *Unable to take risks*: Lack of risk-taking abilities is a major stumbling block to the advancement of one's career. For fear of failure, some engineers stay in their current positions for too long and are not willing to accept promotions that require relocation within the company or to venture out for new positions outside of the company.

   Others feel comfortable with the technical work they do because they are able to control all of the key components of their work (e.g., data, facts, analysis, procedure, and equipment) and the quality of its outcome. Naturally, some of them may feel uneasy when requested to take on managerial responsibilities that involve (1) people who may react differently, (2) data that are often incomplete and inaccurate, (3) objectives that are usually multifaceted, and (4) decision-making tasks primarily based on personal intuition and judgment. The inability to take calculated risks could lead to failure in one's career progression.
4. *Bad luck*: Sometimes, engineers get hurt by business circumstances that are beyond their control or expectations (e.g., mergers and acquisitions, corporate downsizing, change of market conditions, change of business strategies, and advancement of technologies). Career disruptions due to bad luck can happen to anyone. However, one should be able to recover quickly if one's record demonstrates that past

achievements consistently created value to employers, and such value-creation capabilities are widely marketable.

5. *Self-destructive behavior*: Certain engineers exhibit work habits or behavior patterns that are self-destructive. Examples of self-destructive behavior include working in secret, resistance to change, being excessively aggressive, having an uncooperative attitude, picking fights with people, becoming overly argumentative, being readily excitable about trivialities, and displaying a lack of perspective. Such behavior is clearly unwanted in any group environment.
6. *Lack of focus*: Some engineers pride themselves on being a "jack-of-all-trades", getting busily involved in almost everything, but being good at nothing. Failing to focus on creating value to the employer is detrimental to one's own career.
7. *Workplace biases*: Under ideal conditions, all workplaces should be free of biases with respect to race, gender, age, national origin, religious beliefs, and other individual qualities. In reality, some workplaces are managed more effectively and progressively than others. Individual workers need to monitor the real situation at hand and take proactive steps to avoid being hurt by such biases. Engineers serve themselves well by constantly checking against these bias-based failures and proactively managing those over which they can exercise some control.

Appendix 9.C: Tips on Coping for First-Time Supervisors and Managers

It typically takes two to three years for a first-time supervisor or manager to become fully effectual. Here are a few tips that can help the novice to cope during this initially challenging period:

1. Organize the office so that important files and project folders can be located readily.
2. Get a good perspective from one's superior in terms of priorities, strategic plans, previous problems, and vision to operate the unit or department. Do the homework to learn the new languages: finance, marketing, manufacturing, and customer service. Acquire the business perspectives of markets, cost-price position, product distribution, supply-chain management, enterprise integration application, and customer relation management.
3. Obtain training in evaluating staff performance, managing time, and developing multidisciplinary teams.
4. Ready self mentally to assign responsibilities while maintaining control in order to achieve results through people.
5. Communicate own expectations to staff, both individually and in groups, and solicit feedback.
6. Foster relationships with peer managers in other departments.
7. Build the relationship with own superior.
8. Start practicing and polishing your own management styles in order to become increasingly effective.

Humphrey and Stokes (1999) offer another set of nine identifiable people, technical, and administrative skills for frontline supervisors in the new century:

- *People skills*
  1. Communication—ability to adjust own style to correspond with individuals' needs, and an ability to listen to other people
  2. Teamwork—ability to take into account the diversity of other people's backgrounds
  3. Coaching skills—ability to assist other people
- *Technical skills*
  4. Business skills—ability to assess business performance of others
  5. Continuous improvement—ability to constantly update and refine one's own technical skills
  6. Technologically savvy—ability to use modern office equipment
- *Administrative skills*
  7. Project management skills—ability to plan and implement new ideas
  8. Writing and documentation skills—ability to write reports and keep management informed
  9. Resource management skills—ability to network with those who control resources

Over time, first-time supervisors and managers need to demonstrate the ability to build team spirit, create a work environment that fosters self-motivation, solve people and technical problems, and make decisions by integrating technical issues with business issues affecting the company.

Appendix 9.D: How to Manage One's Own Superiors

Both engineers and engineering managers need to properly manage their respective superiors. The superior needs the active support of all employees to succeed, as most of the work is done by the subordinates. On the other hand, all of the subordinates need their superiors' support to move forward along their individual career paths.

The power of a superior should be taken seriously. One of the primary reasons for job turnover is personality conflict with the individual's own superior, not because of technical performance.

It is also of critical importance that one understands the corporate mind-set. Whenever the organization appoints a group leader or manager, the following unwritten rules apply:

1. The organization knows that no one is perfect and that the appointee is no exception.
2. The appointee's strengths are valued more than the trouble caused by his or her weaknesses. Even if the appointee appears to be difficult for some subordinates to deal with, the organization counts on him or her to lead the group and add value. Unless the appointee clearly violates the stated rules, the organization will back the appointee most of the time.
3. To achieve the goals of the organization, the organization trusts the views and desires of the appointee over those of his or her subordinates.

The organization also expects employees to behave in certain ways. These include being attuned to the superior and not insisting that the superior adjust to the employees. Work closely to support the superior and help him or her to succeed. Avoid questioning the superior's judgment and decisions, as the superior typically has access to more and better information and data than the employees and may not be in a position to share such information or data freely.

In readying oneself to manage superiors effectively, it is useful for employees to form the following habits:

1. Understand the business and personal pressure your superior is under, his or her values and motivators (achievement, success, recognition, money, value systems, priorities, principles, and other factors), work style (peacekeeper, conflict lover, riser or setter, channel oriented), and personal style (optimistic, fighter).
2. Expect modest help, and request it only when you really need it. It is better to get help from your own networked coworkers and friends.
3. Be sensitive to your superior's work habits. Watch how he or she receives data and information and works on it. Learn his or her preferred mode of communications—face to face, phone, e-mails, or staff meetings, for instance.
4. Stay in touch with your superior, unless he or she does not want to be bothered regularly.
5. Present materials clearly and without complex details and jargon.
   a. Emphasize the significance (the benefits and realizable impact) of your technical work to the group or company, not its technological complexity, sophistication, or elegance.
   b. Use concise language to elucidate ideas and recommendations clearly.
6. Do not defend a cause unless it deserves it. Keep it in perspective. Do not complain when you do not get all that you asked for.
7. Exercise self-control. Manage your own overreactions or counterproductive behavior.

The following set of guidelines for managing the superior–subordinate relationship is recommended (Goleman (1998):

1. Accept that your superior's support is important to you. Understand how important your support is to your superior.
2. Understand your own response to your superior's style and personality, and manage it. Respect the style and orientation of your superior to his or her work. Understand your response to your position in the hierarchy and how you feel about working within a structure.
3. Learn to take feedback objectively, not personally, and maintain your sense of self and your own uniqueness.
4. Push back when necessary, but only for business reasons and to maintain personal integrity; do not push for political gain or to embarrass your superior.
5. Learn your superior's goals, aspirations, frustrations, and weaknesses. Study and understand what your superior thinks is important. Study and be able to emulate your superior's communications style, for the sake of being heard.

6. Be dependable; follow through on serious requests for information and work output.
7. Display respect to others and expect respect from others in all matters of business and on-the-job interpersonal interactions regarding time, resources, and alternative work styles.
8. Be honest and share all relevant data about the situations and concerns at hand.
9. Keep private any criticism and conflict that may arise between the two of you, and always work for a jointly satisfactory solution.
10. Be manageable by and available to those beneath you.

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10

Creativity and Innovation

10.1 Introduction

Innovation is defined as the act of coming up with something new that adds value to customers and companies alike. Innovations are of tremendous importance to all product/service companies that are constantly in competition for customers and market share. In the absence of innovations, companies will soon lose their relative corporate competitiveness and profitability in today's highly dynamic business environment (Dawson and Andriopoulos 2014).

Innovations require creative ideas. Some but not all creative ideas will lead to innovations. Because creativity precedes innovations, it is important to review various ways in which creative ideas may be effectively generated. Certain thinking strategies may be especially useful in engaging the creative minds of all science, technology, engineering, and math (STEM) professionals to enable them to think creatively.

A new brainstorming concept, DeepThink, is introduced, in which question-based prompts are applied to induce thinking at a deep level to facilitate the generation of novel ideas. Its operation in virtual teams with anonymity and structured interactions (VTASI) is elucidated.

In this chapter, we also discuss first creativity and creative thinking strategies, and then address the fundamentals of innovation, including value chain, processes, and the keys to high-impact innovations. Established practices of developing innovations are then elaborated, including organizational settings, business dimensions, best practices, and some additional guidelines. These discussions will then be followed by selected innovation examples in various industries. Finally, conclusions are offered.

10.2 Creativity and Creative Thinking Strategies

Creativity and innovation confer business advantages and they are important to any enterprise facing a plethora of competition. Creativity focuses on the generation of new ideas, regardless of how useful these new ideas might be in the short or long term. Innovation, on the other hand, centers on adding value to enterprises by implementing and marketing selected new product/service ideas. The extent of creativity is measured by the number of new ideas generated, whereas the extent of innovation is judged by the practical value it brings about. Not all novel ideas lead to adding value. Great ideas with poor implementation will bring forth outcomes of no or only minor significance. Innovation is recognized to be the foundation of sustainable competitiveness and profitability. Its importance is well recognized in the business world (Vogel 2014).

Creativity comes from workers such as scientists, engineers, architects, designers, educators, artists, musicians, and entertainers, who devise new ideas, new technologies, new contents, and/or new business models. Some individuals are more creative than others in generating new ideas. Nikola Tesla said: “There’s no thrill that can go through the human heart like that felt by the inventor who sees some creation of the brain unfolding to success.”

There are certain prerequisites for individuals to become creative. They need to have curious and inquisitive minds, handle ambiguity and uncertainties well, and be highly motivated to act. Training can cultivate the methodologies with which new ideas are generated. Training is also helpful to minimize the constraining effects of past experience and procedure known to inhibit “out of the box” thinking, thus improving their propensity in coming up with new ideas.

Literature research indicates that in general an individual needs about 10 years of incubation time to amass sufficient knowledge to become creative. Even with sufficient knowledge at their fingertips, many individuals do not become creative overnight. Creativity has always been regarded as a desirable but difficult capability to possess.

In many progressive organizations, leaders ask constantly: “How can we up the inventive thought?” For pursuing creativity and innovations, workers go through a creative process. This process is usually initiated by some stimuli, which prompt the individuals to look for new ideas beyond the conventional. Individuals then apply these new ideas to data they have available in order to gain information, which in turn produces knowledge. The newly gained knowledge leads to wisdom, which, when applied properly, delivers innovative outcomes. The innovative outcomes benefit society at large. Figure 10.1 illustrates

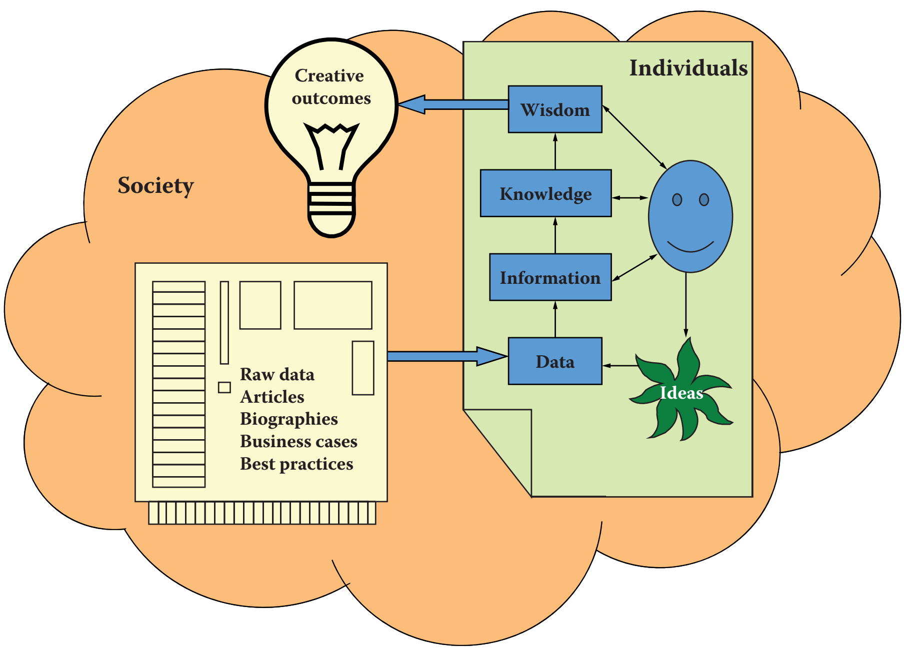

FIGURE 10.1
Creative process.

this process schematically. Specifically, this creative process consists of six steps as follows (Chang 2008a):

1. Excite the inquisitive and curious mind with stimuli.
2. Nurture different thinking strategies to produce new ideas beyond the conventional.
3. Gain new information and perspectives by evaluating data with new ideas.
4. Apply insights and interpretations to glean new knowledge from information.
5. Grow new wisdom from processing and distilling new knowledge.
6. Empower new wisdom to procreate creative and innovative outcomes.

The first letters of these steps constitute the mnemonic of "ENGAGE." An alternative way of describing these strategies may be as follows:

1. Explore metaphors and analogies
2. Notice lessons from failures and mistakes
3. Garner divergent perspectives
4. Adopt idea combinations
5. Go after intellectual prompts
6. Envision relationships graphically

Creativity precedes innovation, which in turn builds corporate competitiveness and sustains enterprise profitability. The six-step *engage* model delineates the creative process leading to innovations and the specific thinking strategies deemed useful in promoting the generation of new creative ideas. The central tenet of this model is that individuals need to leave no stone unturned in the quest to generate new ideas and then to converge on a selected few to shape the innovative outcomes. The combinations of these six thinking strategies may lead to a bubbling of new creative ideas. This engage model could be practically implemented by the DeepThink methodology described in the next section.

It is believed that by aggressively following the above-described model, both in university education and professional development environments, individuals would be able to become creative and innovative sooner, allowing them to make better contributions to their professions, to their enterprises, and to society at large.

10.3 Generation of New Products/Services Ideas by the DeepThink Methodology

Creativity refers to the generation of novel ideas, some of which may become marketable innovations. The generation of creative ideas precedes the development of product/service innovation. "Innovation is the embodiment, combination and/or synthesis of knowledge in novel, relevant, valued new products, processes or services," as suggested by Leonard (2011).

Creative product/service ideas may be traditionally generated by the in-house talents of an enterprise. Enterprises that pursue such an idea generation process in-house are known to enjoy the benefits of complete control and ownership. Creative service ideas may also be generated by an open service innovation strategy (see Chesbrough 2011), which involves customers, supply chain partners, and domain experts on the outside.

In this section, we will introduce a specific methodology to invent new ideas involving the use of virtual teams, which may comprise of primarily company-internal people or selective members from company-external sources or both.

10.3.1 Background

It is well known from the literature that the personal background knowledge and thought process due to prior training and work experience influence the way each STEM professional will think when challenged by an external problem or issue. The outputs are usually somewhat predictable (see Figure 10.2).

In order for such an individual to think "out of the box," the use of external stimuli (e.g., question-based prompts) maybe useful, as shown by New Solutions #1 to #4 in Figure 10.3. The concept illustrated in Figure 10.3 is based on the assumption that STEM professionals may modify the way they think upon receiving external stimuli, and may thus come up with new solutions. As their minds are being disturbed, they could engage in more free association, thus possibly leading to more creative ideas. By implementing this concept repeatedly, an iterative process involving groups of participants may be devised to facilitate the generation of new product/service ideas. Figure 10.4 illustrates this process.

Specifically, when an individual STEM professional receives a set of question-based prompts, he or she will offer the expected conventional solutions, as defined by his or her prior training and work experience, as well as some possible new solutions induced by these external prompts. In a group setting, all these outputs are to be collected, screened, and evaluated. This process is illustrated by the selection lens in Figure 10.4. By eliminating various solutions that are commonplace or nonnovel or both, the residual solutions will become "better" ideas that could serve as the initial starting ideas for the next iterative round of idea generation. Individual professionals in the team reflect on this new set of "better" ideas and process them while being prompted by additional question-based external prompts. The process continues to yield an improved new set of "better" ideas.

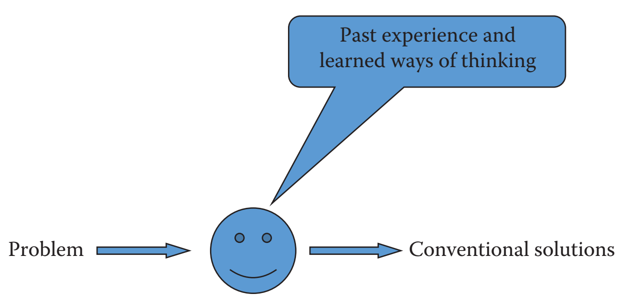

FIGURE 10.2
Traditional ways of thinking.

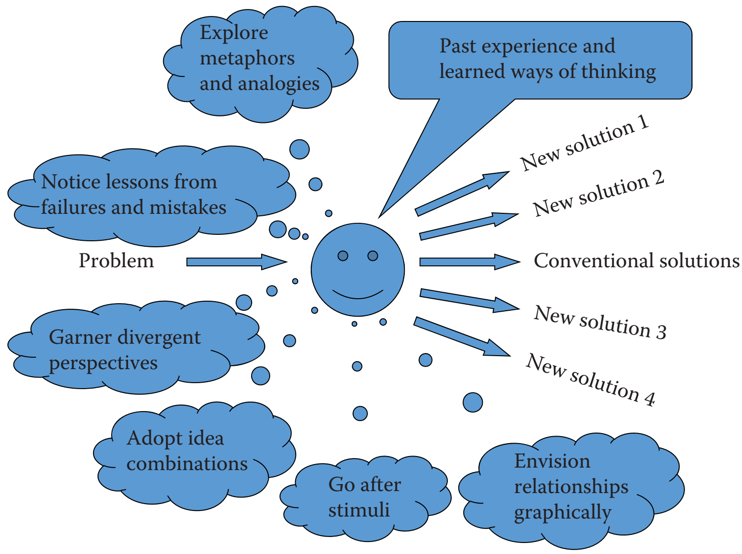

FIGURE 10.3
Modified model of out-of-the box thinking.

This process stops when a sufficient number of "better" ideas have been generated. The final output of the team will be a set of novel ideas, which are brought into being by this multiple-round process.

This team process may be applied in parallel involving several separate teams that address the same problem or opportunity. It may also be applied in a series in that, ideas from previous teams are introduced as initial inputs to the current teams.

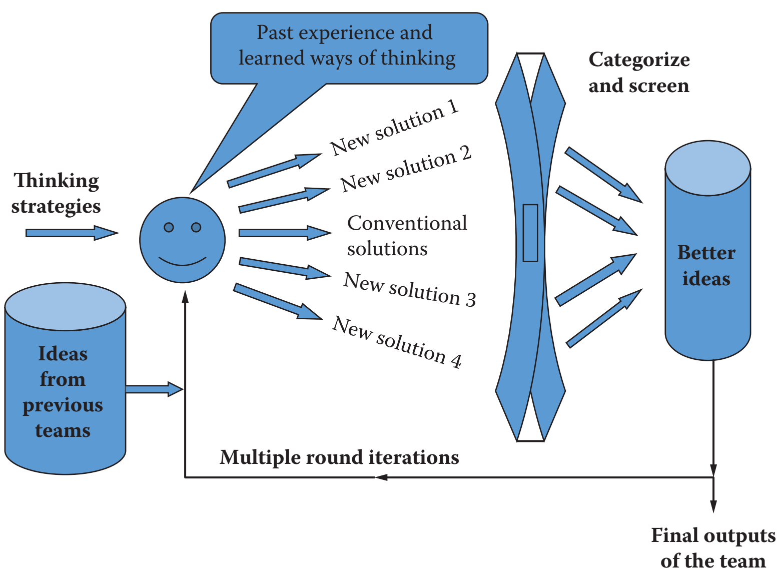

FIGURE 10.4
Iterative routine to generate innovative ideas.

10.3.2 Question-Based Prompts

The abovementioned question-based prompts play a central role in this multiple-round idea generation process. Chang (2014) has compiled a set of DeepThink prompts at the University at Buffalo. They are delineated as follows (see additional details of specific question-based prompts included in Appendix 10.A):

1. *Delve*: To delve is to dip deeper down to the components and subcomponents levels of an idea/concept in order to exploit the interfaces therebetween, and the roles and value contributed by these parts.
2. *Envision*: To envision is to think divergently and to project an idea forward into the future.
3. *Exchange*: To exchange is to replace or swap components in order to add value.
4. *Perturb*: To perturb is to seek novelty refinement by slightly modifying the concept's attributes and features. Raise "what-if" questions.
5. *Transpose*: To transpose is to invoke lateral thinking by looking at the same concept or issue from several different perspectives.
6. *Harness*: To harness is to discover and redeploy the wisdom contained in other ideas for new circumstances.
7. *Integrate*: To integrate is to combine ideas and concepts in different contexts to form new ones.
8. *Nurture*: To nurture is to modify and adjust separate and unrelated concepts/ideas to form something new.
9. *Knock*: To knock is to knock down limitations, negative driving forces, assumptions, and conventional wisdom, which may have inadvertently constrained the value of the concept.

The first letters of these nine thinking strategies constitute the mnemonic "DeepThink," and hence the name. They form a set of thinking strategies, which are expected to be generically applicable to the production of novel ideas in different fields (see Figure 10.5).

Not all of these nine thinking strategies will apply to each and every issue, problem, or opportunity we encounter. If a given sample question does not appear to be relevant to a given issue, participants are advised to just skip that question and continue with the next. Most productive participants are those with free spirits, being curious and risk taking, and are proficient in inductive thinking. Producing inventive ideas of the "blow-the-roof-off" type would require all the mental and physical reserves the team could summon.

The DeepThink prompts are designed to promote the creation of novel ideas. For an idea to be patentable, being novel is just one of four requirements. The other three requirements are (1) being of a subject matter that is eligible for patent protection, (2) being nonobvious to people skilled in the art, and (3) being useful. Any invention is novel if it has not been known, used, or disclosed by others before the date of invention. It may not be simple improvement ideas, which would be obvious to someone skilled in the arts. The patentability requirements vary somewhat from one country to another. The patentability issue should be addressed during the innovation development process.

Not all novel ideas are marketable. However, ideas that are marketable but not novel do not provide a long-term sustainable advantage to the enterprise, as such ideas can be readily copied by competitors. It is also advisable that the primary emphasis of generating

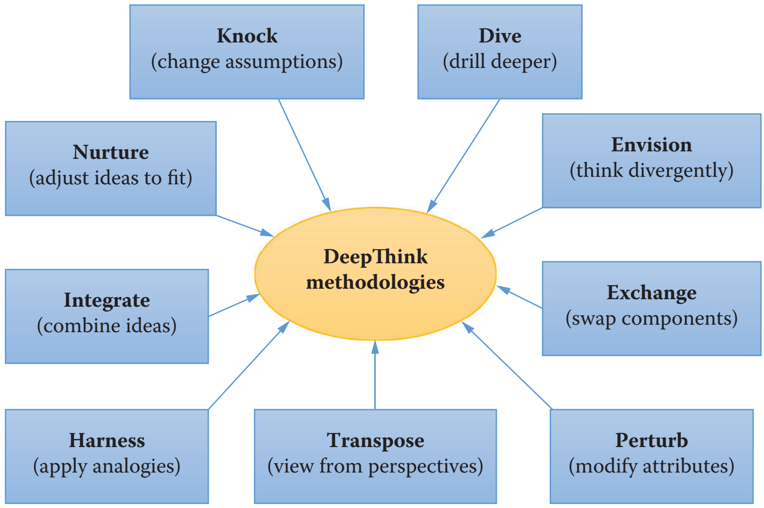

FIGURE 10.5
DeepThink methodologies.

creative ideas be placed on the core product/service elements, involving (1) knowledge and insights (e.g., currency, uniqueness, and access), (2) newness and significance of benefits realizable to the intended users, and (3) technological means to enable the consumption of the product/service. Thus, the thrust of employing the DeepThink prompts should be to identify novel ideas, and to seek increasingly higher levels of their novelty.

The core element of a product/service idea that offers complex value propositions could be composed of a group of subelements, some of which should be novel in some ways. If possible, the availability of these subelements may be secured through proper licensing arrangements with outside inventors.

Appendix 10.B lists a number of illustrative novel ideas that could be generated in response to some of the question-based prompts contained in the DeepThink methodologies. As the saying goes: "Never doubt the power of examples," a careful review of these illustrative examples could enable the readers to better appreciate the practical utility of these question-based prompts.

10.3.3 Organize VTASI Teams to Bring Forth Creative Ideas

Teams are one of the most widely utilized organizational forms of creativity pursuits, as participants of diversified background could be easily assembled to promote mental cross-fertilization between different disciplines and innovation by exaptation. As summarized by Chang (2011a), there are three types of teams: (1) standard teams in which participants meet face to face, (2) virtual teams in which participants interact remotely, and (3) virtual teams in which participants interact remotely while remaining anonymous to one another. Each of these teams possesses advantages and disadvantages.

It is proposed that the way to effectively utilize the above-described DeepThink methodologies in a group environment is to utilize the third type, the VTASI team. Participants on the VTASI team need to possess the right qualifications and domain knowledge.

A team leader should be appointed, who will specify the project objective. As Charles Kettering said: "A problem well stated is a problem half-solved." He or she will further exercise the leadership role of managing the team, preparing the team members with required communication technologies, securing the essential supports, explaining the use of DeepThink methodologies as question-based prompts, and ensuring that all members understand and accept the team objective to create novel and potentially patentable ideas that could form the basis of new product/service offerings The team leader is expected to have the mettle to accomplish these tasks.

The team leader would then initiate a first-round deliberation via e-mails, while advising all team members to utilize some of listed question-based prompts. His or her personal dedication toward this team effort inculcates a sense of responsibility and urgency among the team members. He or she would collect all electronic outputs from the team members, prune the results by eliminating redundancies, post questions to further induce creative ideas, acknowledge excellent outputs of specific individuals, offer constructive comments and feedback to guide the team toward certain potentially more fruitful areas to pursue, and recycle the residual ideas back to the team. The purpose is to enable the team to delve deeper in the subsequent rounds.

The pruning process is primarily for zeroing in on relatively novel and potentially patentable ideas, from the perspectives of technology, application, and/or utilization of assets. The final set of team output are ranked ordered by a vote of all participants. This multiple round of iterations is described in Figure 10.4.

10.3.4 Advantages of Engaging VTASI Teams to Generate New Ideas

There are a number of advantages associated with the use of VTASI teams. In such a team, every participant may express his or her own ideas freely and uninhibited. It is known from Kohn and Smith (2010) that individual brainstorming may be better in generating a lot of new ideas than using face-to-face group-based brainstorming settings, because of the shortcoming of "collaborative fixation," the tendency that people's thinking patterns are influenced by ideas presented by others, thus possible channeling to an eventual conformity of ideas. Indeed, generating a lot of ideas is very useful, as Thomas Edison said: "To have a great idea, have a lot of them." The interactions between the participants are then ensured by reading the summary reports, in which all relatively novel ideas are categorized without disclosing the identity of their individual authors. From the ideas listed, participants will recognize the relative merits, the viewpoints they express, thus enabling them to react or respond in the subsequent rounds of interactions. These interactions will be in the form of building on others' ideas, combining ideas already in existence, introducing new ideas by analogy, or modifying some of their idea-building elements. The next critical step is thinking, according to Albert Einstein who said: "Discovery consists of seeing what everybody has seen and thinking what nobody has thought." The components of individual creativity are identified by Ness (2012) to be motivation, creative thinking skills, and expertise. In VTASI teams, these critical thinking skills are promoted via the DeepThink methodologies presented before.

Other advantages of VTASI teams include the following: (1) the team avoids the known shortcomings of face-to-face meetings, such as social loafing, evaluation apprehension, production inhibition, and dominance; (2) they can be readily implemented on a global scale, speedily and cost-effectively, involving experienced participants with diversified backgrounds residing anywhere; (3) participants are engaged only on a part-time basis and for a very short period of time, thus permitting all of them to continue pursuing their respective full-time work assignments; (4) the team can be rapidly assembled and disbanded, permitting its deployment in a rather agile and cost-effective manner; (5) VTASI teams may serve as a screening tool for a product/service enterprise to identify creative professionals, who can then be engaged to form increasingly creative teams in the future; (6) VTASI teams may be deployed in series, in which the novel outputs of some teams are used as initial inputs to subsequent teams, in order to procreate deeper and increasingly novel ideas for the project at hand; (7) companies may use VTASI teams to train future team leaders who are then empowered to spearhead the development of creative products and services; and (8) VTASI teams could serve as a useful tool for colleges to train the creativity and innovative capabilities of students.

The VTASI team designs have been successfully tested at the University at Buffalo, addressing several innovative projects (from 2009 to 2012): (1) Choosing Career Paths (Chang 2012), (2) USPS Profitability Problems (Chang 2011b), and (3) Business Enhancements to FedEx, Fidelity, Travelocity, and Beach Services (Chang 2011c). The mnemonic VTASI stands for virtual teams with anonymity and structured interactions. It may also stand for "venturing together achieves superior ingenuities."

10.3.5 Observations and Team Survey Results

It is generally expected that intra-team competition plays a role among the team members. To promote such a constructive competition, the team leader is advised to actively recognize and reward team members for outstanding performances.

The VTASI team leader performs a number of other important tasks. These include (a) maintaining a close and admirable working relationship with each participant (e.g., evaluating performance, offering feedback, answering individual questions via e-mails, injecting questions to challenge, stimulate, redirect and support the individual efforts); (b) assisting the team in pruning all ideas that are obvious and of low-level innovative content in order to conserve thinking efforts; (c) organizing and presenting the team outputs at each round in ways that are easy for team participants to process; (d) managing the idea generation process (e.g., guiding the team to utilize the DeepThink prompts by offering specific examples or answering questions); (e) enforcing rules to discourage nonconstructive criticism of others' ideas; and (f) discouraging any specific individual from exerting dominance in idea exchanges. The team leader lights a fire under the team members to get the right things done.

Studies in the literature have pointed out that when creative people are challenged by other equally creative people on the same team, they could work even better, as more creativity may be stimulated by interactions between them. The VTASIs can make it happen readily by setting up a number of parallel teams to pursue the same project. After the first round, members who have demonstrated remarkable creativity could be grouped together in new teams to pursue the later rounds.

Extensive surveys were conducted at the University at Buffalo after each project involving VTASI teams. By and large, most of the survey responses were positive. Participants were generally in favor of the use of individual brainstorming methodology, while remaining anonymous. Some participants preferred to have additional group-based meeting for face-to-face discussion of the results after each round. A preproject introductory meeting was viewed to be useful, so that everyone is brought to the same starting page. A common set of reading materials could also be useful, so that all participants have a similar understanding regarding the project at hand.

Other improvement ideas suggested include: (a) Additional examples to illustrate the use of DeepThink methods in a variety of situations. (b) Offer individually customized feedback and leading questions in order to guide participants to drive for a deeper level of creative thinking. (c) Allow some Internet-based forms of optional cross-communications between the participants, without bringing about social loafing, evaluation comprehension, production inhibitation, and other such unwanted effects of group brainstorming. (d) Continue to improve the universal applicability of the DeepThink methodologies. (e) Add voting opportunities for participants to select the top novel ideas at the end of each round of deliberations during the idea generation process.

Some of these improvement ideas will be included in our future studies on the use of VTASI teams for generating novel ideas in various fields, especially in instances wherein breakthrough types of ideas with a high level of novelty are desired.

10.4 Fundamentals of Innovations

In this section, we address the fundamentals of innovation, comprising the innovation value chain, the innovation development process, and the keys to high-impact innovations.

10.4.1 Innovation Value Chain

The innovation value chain (Hanson et al. 2007) consists of three sequential processes: idea generation, idea development, and the diffusion of the developed concepts. Some companies may be strong in one and weak in another. The ultimate success of a company's innovation pursuits depends not on its strengths in any of these processes, but on the weaknesses in any of them. Like in a mechanical chain, the overall strength is determined by the weakest link in the chain. Companies must understand their own strengths and weaknesses in all these processes and take action to strengthen their weak processes, in order to achieve an acceptable outcome in their innovation value chain.

10.4.1.1 Idea Generation

Innovative ideas may come from creative people of different sources. Table 10.1 shows a list of known sources of "big ideas," based on a survey conducted by IBM Business Consulting Services (Violino 2006).

The concepts of open innovation and open-market innovation are well known in the business literature (Chesbrough et al. 2015; Chesbrough 2005; Griffin et al. 2014). The benefits of treating customers and suppliers as strategic partners are obvious. For example, physicians may know about opportunities for new capabilities to make their care delivery more effective. Debruyne (2014) and Leonard (2002) suggest that companies ask customers for the outcomes they want, not for a particular product/service feature that they think they need. Christensen (2013) explains the rationale of not asking existing customers solely for ideas, thus likely missing some simpler needs of lower-end customers in rapidly growing segments.

Idea generation may be improved by building an external solution network. As practiced by Proctor and Gamble (P&G; Huston and Sakkab 2006), customer needs are first translated into technology briefs, which include the problems to be solved. These briefs are then sent through the company's solution network, which includes technology scouts, suppliers, research laboratories, and retailers to solicit possible solutions.

Idea generation may also be enhanced by creating a solution-seeking website (e.g., Eli Lilly's InnoCentive—www.innocentive.com). Over 80,000 research participants (called

TABLE 10.1

Sources of Big Ideas

Source	Respondents (%)
Employees	41
Business partners	38
Customers	37
Consultants	22
Competitors	20
Associations, trade groups	18
Sales or service units	18
Internal R&D	17
Academia	13

Source: IBM Business Consulting Services.
Note: Multiple choices allowed.

solvers) in over 170 countries are currently registered at the site to help its clients (called *seekers*) to find solutions to difficult R&D challenges. The clients include Dow Chemical, P&G, Eli Lilly, and 20 plus others. When seekers confront a particularly difficult research challenge, they post their requirements to InnoCentive's solver network and offer a bounty to anyone who finds a solution. The ultimate price for the solution winner is $20,000. The success rate of InnoCentive was said to be about 50%.

Alternatively, companies may set up a discovery network. Siemens is known to have set up a 15-person scouting unit in Berkeley, California, to cultivate personal relationships with scientists, engineering doctoral students, venture capitalists, and entrepreneurs as well as government laboratories and corporate research centers. They keep track of emerging technologies and business ideas and constantly feedback their learning to allow Siemens to selectively take advantage of such insights in order to achieve time-to-market and technological leadership advantages. Similarly, Intuit sent out a 10-member team to learn and observe how small business owners do their financial books. The result is the Simple Start edition, which became a best seller for Intuit.

Certainly, companies may also build internal cross-unit networks in order to tap into the special talents from within. P&G created 30 "communities of practices (CoPs)" each focused on an area of expertise, to encourage interactions between workers of diversified backgrounds. These communities solve specific problems that are brought to them. Members of these communities participate in monthly technology summits with business representatives.

How could innovations be promoted by networking? Personal networks are extremely important for innovative pursuits. Companies should foster innovation by creating networks that facilitate interactions between employees and others with specific know-how and diversified backgrounds.

A successful network delivers three advantages: (1) private information, which is not readily available from public sources; (2) diverse skills sets, which greatly compliment one's own knowledge and experience; and (3) information brokers, who are linked to useful networks to access information if needed (Uzzi and Dunlop 2005). For a network to offer these advantages, its members should preferably have diversified knowledge and experience, be able to serve as linkages to other networks of diversified people, and can offer private information when trust has been established.

In general, people tend to form their network by predominantly applying the "self-similarity" principle. The self-similarity principle states that people tend to make friends with those who have a similar background, work experience, and outlook. They also should not form networks by applying the "proximity" principles, thereby becoming closely connected with people who work in nearby offices or neighborhoods. The drawbacks of such self-similarity or proximity networks lie in their lack of diversity in opinions, values, judgments, and worldviews. Too much similarity restricts one's access to discrepant information.

Instead, people should pursue the "shared activities" principle to form networks, by making friends through group activities that pursue high-stakes activities of common interest. Examples of such group activities include community service ventures, interdepartmental initiatives, voluntary associations, cross-functional teams, charitable foundations, for-profit boards, and others. The mutual trusts developed among participants in such activities could form a very solid foundation for personal interactions and knowledge interchanges.

Important for innovation is the feedback secured from networks that are composed of trustworthy people with diversified perspectives.

MacCormack and Forbach (2008) point out that companies that are successful in pursuing innovation via collaboration pay attention to four P's: (1) People—select people on soft skills (communications) and train partners. (2) Processes—teams from different cultures have different strengths and working methods, which need to be matched with their assigned tasks. Frequent communications is a must to resolve problems. (3) Platform—apply the same infrastructure (tools and standards). (4) Program—a coherent program to continuously monitor and improve collaboration efforts (not as individual projects). For example, the Boeing 787 Dreamliner project involves 50 partners at 130 locations. The key to competitive advantage lies in the collaboration of so many partners, so that their individual expertise can be effectively merged to create innovative outputs.

Example 10.1

Transposing an old known idea to a new unrelated field is a well-known technique to innovate. How can company management foster this specific technique of creativity?

Answer 10.1

For such a technique to be effective, companies need to motivate people with diversified experience and knowledge to collaborate extensively and have a risk-tolerant organization in place to recognize and reward a superior performance in a timely manner.

Hargadon and Sutton (2009) suggest that an effective innovation system can be created by the right organization and attitude. Their research pointed out that the best innovators systematically use old otherwise disconnected ideas as the raw materials for new innovations. Robert Fulton applied the old steam engine idea that was used in mines for 75 years to power boats.

Successful innovators of companies systematically go through the knowledge-brokering cycle of identifying good ideas, keeping ideas alive, imagining new uses for old ideas, and testing promising ones. Thomas Edison said: "To invent, you need a good imagination and a pile of junk."

10.4.1.2 Idea Conversion and Diffusion

There are two strategies that could improve the success of the idea generation process, namely, multichannel funding and safe haven.

Shell Oil created a 25-person unit, GameChanger, with an annual budget of $40 million. This unit evaluates and funds business ideas submitted by Shell employees, typically to the tune of $300,000–$500,000 per project. Successful projects are subsequently funded by Shell divisions.

Safe havens are business units designed to nurture new business ideas and projects and shield them from the short-term thinking and budget constraints that pervade in-line organizations. Line managers participate on the board that governs these safe havens. Safe havens are allowed to operate autonomously in separate geographical locations.

A champion is very much needed to preach and broadcast the value of new ideas, and to spearhead the diffusion process throughout a large organization (Vishwanath and Barnett 2011).

10.4.1.3 Manage and Monitor the Value Chain

One way to constantly improve the innovation value chain is to set up performance indicators for each of its three component processes and then steadily monitor their progress. For idea generation, these indicators may simply include the number of high-quality ideas produced within and across units and from outside the firm. For idea conversion, the idea selection process may be evaluated by the percentage of all ideas generated that end up being selected and funded, whereas the development process could be gauged by the percentage of funded ideas that lead to revenues, and the number of months to first sale. To monitor idea diffusion, the percentage of penetration in desired markets, channels, customer groups, and numbers of months to full diffusion could be used (Hansen and Birkinshaw 2007).

There are a lot of "best practices" in innovations available in the literature. But one size does not fit all. The value chain concept and its management allow the proper choices to be made as to which best practices are to be introduced when and where in the organization, so that the overall innovation process is effectively advanced.

10.4.2 Innovation Development Processes

According to Kaplan and Norton (2004), basic innovation development processes comprise the following four processes: (a) identify opportunities for new products/services; (b) evaluate and prioritize ideas for development; (c) design and develop the new products/services; and (d) bring the new products/services to market. These processes will be discussed next.

The objectives of *identifying opportunities* are to anticipate future customer needs and then to discover and develop new, more effective or safer products/services. The key metrics to measure progress are (1) the time spent with key customers learning about their future needs, (2) the number or percentage of new products/service projects launched based on client input, (3) the number of new concepts presented for development, and (4) the number of new value-added products/services identified.

Innovation opportunities of great value are generally of the following types: (1) ideas that enhance functionality aspects and performance attributes, (2) ideas that shorten the time-to-market requirements, (3) ideas that extend an existing product/service to applications beyond the one initially targeted, and (4) ideas that reduce product/service prices for customers.

New ideas need to be carefully *evaluated and prioritized* in view of the respective potential market values, time lines, risk profiles, and resources required for development. The potential market value may be estimated using probabilistic models. The possibility of joint development should also be considered.

Many companies utilize the stage-gate process to guide *the development process* of products/services, so that specific objectives are met at predetermined stages. Each gate represents a go/no go decision in view of the advancement of technologies, customer preferences, competitive actions, and governmental regulations. The stage-gate process can also be used to provide a discipline for the development process of services, although it is less formal than in developing products. Figure 10.6 illustrates the stage-gate process that is modified for both products and services.

In developing products/services, customer input is sought at all stages. The design/development efforts are successful if the resulting products/services have the functional features desired by the customer in the marketplace, possess the acceptable product/service quality, and are deliverable at a price that enables the company to earn a satisfactory profit margin. The more a company understands its customers' specific behavior and needs, the less likely its product/service innovations can be readily copied by the competition.

After the launch of the new product/service, companies actively provide after-sale support to ensure that the marketed product/service delivers the anticipated value to the targeted customers. This involves communications, problem diagnosis, troubleshooting, and remedial actions, if any.

For a service provider to be successful in the marketplace there must be something for it to stand out, be it a unique service benefit, a novel delivery mode, or a low cost. These must be the foci of company innovation drives (Berry et al. 2006).

Examples of superior service contents include the following: Starbucks is known for its unique "store atmosphere" that is enhanced by the physical layout, pleasant employee interactions, and the special coffee drinks and foods they serve. Cirque de Soleil offers a unique combination of highly skilled acrobats and dances, not seen before. Barnes & Noble create a seating area for customers to browse its books while enjoying a drink.

Examples of achieving differentiation by offering a superior delivery mode are the following: Ball Memorial Hospital redesigned its emergency room reception area to facilitate the rapid processing of patients and to make them more comfortable. Enterprise Auto

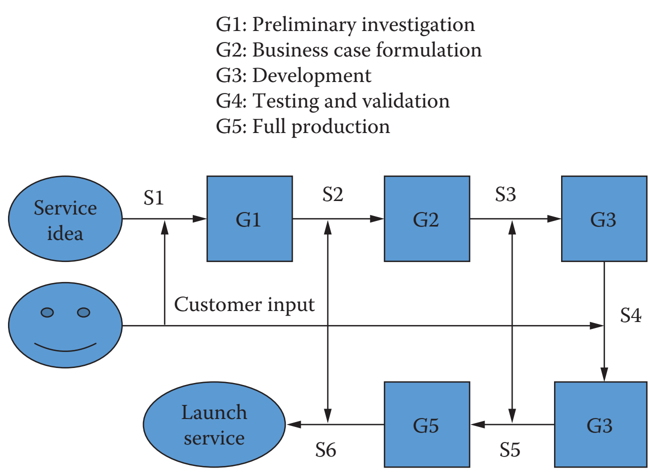

FIGURE 10.6
Stage-gate process for innovation development.

locates its car rental stores to where local customers are in order to better serve those who have short-term transportation needs due to car repairs. Walgreen stores remain open 24 hours a day and are conveniently located at major cross-sections of main streets in a city. Similarly, Denny's and Perkins are known to be open 24 hours a day for the convenience of some night folks. Online degree programs represent the innovation disruption in delivering college education, spearheaded by the University of Phoenix, which becomes the world's largest university with over 60,000 online students. Online degree programs are known to please customers who would otherwise not be able to gain the educational experience. However, not all hiring companies in industry welcome graduates of online degree programs because of the divergent reputation and learning quality of these programs.

Other services distinguish themselves by lower prices. Southwest Airlines offers a significant discount in airfares by using a common aircraft type to reduce maintenance cost, flying a limited number of service routes to optimize the utilization of equipment, eliminating seat assignment to speed up its boarding operation at the gates, and reducing onboard food services to cut costs. Alamo is a low-cost car rental company that is known to have placed its rental offices far away from the airport to save operational costs. Hilton Hotels is known to have offered groups of hotels at lower price ranges in order to broaden the customer niches they can serve.

Christensen and Anthony (2004) point out specific examples of achieving marketplace acceptance by lowering prices in health care, education, and law. Specifically, adjusting downward the service features to align with the affordability and needs of lower-end customers segments represents "innovative disruptions." Using paralegals to take care of the less-demanding tasks of a law firm will allow a "good enough" legal service to be provided to more people at a lower cost. Producing software to promote self-help in legal matters is another viable option. Nurses can follow the diagnostic procedures developed by physicians. In Minnesota, QuickMedx kiosk, which is located in a local grocery store and run by a nurse practitioner, dispenses prescription medication for certain common illnesses within 15 minutes. CNN is known for its novel programming strategy of offering news highlights on a 24 hour basis. eBay is the primary online market for buying and selling almost anything. FedEx prides itself on being the on-time delivery package service that is extremely dependable. Google provide a superb delivery of search results with speed and relevance. Netflix created a unique way of communicating with and delivering rental CDs to its customers. Banks offering automated teller machines (ATMs) enhance customer loyalty by enabling 24 hour access to deposit and withdraw transactions. Other services offer web-based frequently asked questions and self-service at no cost to customers, in order to enhance customer experience.

For both "concurrent and separate" services, companies (1) focus on creating a culture that supports employee performance and continuous innovation, (2) create a superior service benefit to customers, (3) simplify service designs to raise customers' affordability for services, and (4) empower a champion to lead the innovation process in securing a strategic differentiation. Furthermore, for "concurrent" services, companies (5) emphasize the development of a scalable business model in order to enhance productivity, (6) train employees and motivate them to service customers well, and (7) invest in the service "factory" by offering a pleasant customer experience (e.g., physical layout, unique benefit, pleasant employee interactions). On the other hand, for "separate" services, companies (8) innovate to raise the level of operational excellence and (9) build brand to overcome risks perceived by customers in selecting "sight-unseen" new innovative services (Berry et al. 2006).

Example 10.2

In the new millennium, innovative ideas, rather than physical assets, will enable companies to compete efficaciously in a global economy. Usually, innovative ideas come from knowledge workers who are typically inventive, independent, and mobile. No single company is capable of "chaining" down these workers, as they are happy to be there for now, but ready to move on at any time.

It is likely to be a major challenge for engineering or technology managers to foster innovation on a continued basis in such an environment. What might be a good strategy for engineering and technology managers to adopt in order to secure a constant flow of innovations potent enough to sustain the relative competitiveness of their employers?

Answer 10.2

During the last century, a number of well-known companies (e.g., Apple, IBM, AT&T, DuPont, GE, and Merck) achieved remarkable business success by emphasizing R&D in-house and innovation on the inside. They proudly advertised the number of U.S. patents they received per year as an indication of their inventive power. They kept a large number of experts on their payroll to foster innovations. Many of these giants have since left their historical mission of inventive discovery. Some have also abandoned the past practice of not sharing with others those inventions that did not fit their respective corporate strategies at the time.

Companies in the knowledge economy have implemented a flexible technology strategy with great success. Known examples include Microsoft, Cisco, Dell, and Pfizer. Because skilled workers are mobile, companies can no longer count on in-depth development of innovations on the inside. In order to secure a constant inflow of creative ideas, they pursue open innovations (e.g., by acquisition, joint venture, codevelopment, or contract research) deemed useful to foster their corporate objectives. The emphasis has been shifted from in-depth innovation within a discipline to innovation with breadth and integration across disciplines.

P&G is known to be an aggressive acquirer of creative ideas from the outside. In 2001, 10% of P&G products came from outside sources, and this percentage is expected to have risen to 50% by 2006. P&G has also decided to make a patented technology available to outsiders, including competitors, if it is not used by at least one internal business unit within three years (Chesbrough 2005).

To meet the new challenge of creating a constant flow of creative ideas, engineering and technology managers must scan promising innovations on the outside (universities, start-ups, competitors, and others) and integrate them for profitable internal applications. Any inside innovations that do not conform to the corporate objectives are to be aggressively marketed to outside companies to generate licensing revenues.

10.4.3 Categories of Innovation in Practice

Boston Consulting Group defined the most innovative companies in the world for 2014 (Baer 2014). The top ten innovative companies are: (1) Apple, (2) Google, (3) Samsung, (4) Microsoft, (5) IBM, (6) Amazon, (7) Tesla Motors, (8) Toyota Motors, (9) Facebook, and (10) Sony. A number of useful innovation practices have been defined in their study.

In the past, innovation was about technology and control of quality, cost, and efficiency. Today, it is about creativity and growth. In general there are three types of innovations:

1. *Technology innovations* (Blackberry made by Research in Motion Ltd.).
2. *Business model innovations* (Virginia Group applies a hip lifestyle brand to airlines, financial services, and health insurance; Bharti Tele-Ventures Ltd. outsources everything except marketing and customer management).

FedEx is known to have implemented four specific business model innovations:

1. Branching out into new businesses in order to burrow deeper into the supply chains of customers.
2. Expanding into fast-growth markets (e.g., China).
3. Improving package-tracking capabilities and other customer-oriented features.
4. Adopting a "here, there, and everywhere" strategy (e.g., created 1450 Kinko's outlets).

Kroger, a traditional grocery chain with annual sales of $66 billion in 2006 and 3650 stores in 31 states, expanded its businesses to include credit cards, Kroger-branded ATM machines, mortgages, home equity lines of credit, and insurance coverage (identity theft, home, life, and pet) in order to "drive more people to the store and bring them back."

Wal-Mart, another grocery chain, added prepaid Visa debit cards and other money services and introduced "MoneyCenter" alcoves in stores.

3. *Process innovations* (operational improvement—Southwest Airlines).

The study also identified several innovation obstacles, which are prevalent in industry. These include: (1) slow development time, (2) lack of coordination (flexible organizational setting, new leadership positions, diversity of team, membership); (3) lack of culture (rewards, metrics to monitor progress, risk management)—culture is defined by the CEO; and (4) getting good consumer insights (observe what customers do and understand the local culture, behavior, and fashion).

For companies to achieve success in innovation, these obstacles must be overcome.

10.5 Innovation Management

In this section, we will discuss the organizational settings that are conducive to innovations, business dimensions along which innovation could create corporate competitiveness, best practice for managing creative people, some additional guidelines for managing innovations, and protection of inventions and innovations.

10.5.1 Organizational Settings Conducive to Innovations

Brown (2005) argues for an open "pull-type" of organizational form to foster innovation. In case demand is well known, the traditional push system (top-down, centrally managed, routine operation) is best in efficiency. However, when future demand is not readily forecast, then a pull system is much more agile, as in the case when consisting of many partners, each having special skills and technology, innovations can be pulled together for a given new demand. Table 10.2 illustrates the difference between the organizational forms of push and pull types.

Companies interested in fostering innovation are strongly advised to adapt the "pull" type form, so that they can increase opportunities for collaboration, create closer relationships with customers, receive more rapid feedback, attain greater scalability, and network

TABLE 10.2

Push versus Pull Systems

#	Items	Push	Pull
1	Basic assumption	Demand is foreseeable	Demand is not readily forecast
2	Key characteristics	Program defined by manuals and procedures	Platform being open ended
			Loosely coupled modules
3	Operational style	Rigid	Agile
4	Key requirements	Discipline	Open-mindedness
5	Worker orientation	Closely directed employees following orders	Self-directed networked creators
6	Advantages	Tight control	Emphasis delegation
		Efficiency	Flexibility
7	Disadvantages	Inhibit innovation in closed environments	Foster open innovation with partners

with deep sources of competitive advantage. Examples of "pull" platforms in the service industries include Amazon.com, Netflix, and Expedia.

Since 2002, John Deere has created 300 CoPs to drive innovations by facilitating connections among knowledge workers (Suave 2007). In each of these practice-based communities, which cover best practices, training, mentoring, and peer resources, subject-matter experts are available via e-mail, face-to-face meeting, or through online conference.

IDEO, Palo Alto, California, is a product design company known internationally for its innovative skills. The company follows the strategy of observing, brainstorming, prototyping, and implementing to pursue innovations. As pointed out by Kelley (2005), its success in innovation is primarily due to 10 capabilities that it systematically nurtures and develops:

1. Observes and studies customer behavior.
2. Conducts experiments to continuously learn.
3. Brings findings in other industries to the project at hand.
4. Has perseverance to overcome difficulties.
5. Facilitates collaboration among team members.
6. Organizes the right set of team members.
7. Designs to meet customers' needs.
8. Promotes creativity by changing the physical environment.
9. Anticipates customers' needs.
10. Motivates the team.

A clear focus on customers, together with experimentation and internal collaboration, represents IDEO's model for innovative success.

Example 10.3

It is known that managers have a direct influence on the outcome of a company's innovation program. How can company management effectively foster innovation?

Answer 10.3

There are quite a few actions that company management could take to promote the cross-disciplinary collaboration of people with diversified skills, knowledge, and experience and thus enhance the probability of success in the company's innovation programs.

As indicated in Mendonca and Sneader (2007), Bill Campbell offers a few tips to managers in order to foster innovations:

1. Empower engineers
2. Create an innovation culture
3. Lead with people who care about building durability and lasting value
4. Focus on things that are really differentiable
5. Support innovations (fellowships, awards, bonuses, extra vacations, etc.)
6. Technology centered
7. Involve marketing to understand the "problems"
8. Set high expectations
9. Take risks and anticipate some failures
10. Hire creative people
11. Screen ideas and projects from the viewpoint of a venture capitalist

10.5.2 Business Dimensions to Focus

Sawhney et al. (2006) point out that there are many business dimensions along with innovation that could create corporate competitiveness. Neglecting some of these dimensions may cause companies to miss valuable growth opportunities.

1. Service offering: The functional features.
2. Platform: Modular components of the service, which can be used to create related new services.
3. Solutions: The real value that customers get.
4. Customers: Future needs.
5. Customer experience: The pleasure conveyed to customers by the interactions.
6. Value capture: Profitability to service provider.
7. Processes: Streaming the production process to be cost-efficient.
8. Organization: Change organization to improve customer supports.
9. Supply chains: Engage suppliers to improve offering.
10. Presence: Change the touch points to improve customer experience.
11. Networking: Intelligent offerings via networks.
12. Brand: Create brand to reduce risks perceived by customers.

From the customers' perspectives, there are nine value dimensions that are important. Customer value is created by having achieved satisfaction along one or more of these dimensions. Innovations along these nine dimensions tend to effectively create competitiveness in the marketplace. Figure 10.7 illustrates these nine dimensions and the foci of innovations that are needed to achieve each.

It is not necessary that companies pursue innovations in all these dimensions in order to succeed in the marketplace. Oftentimes, it might be sufficient to focus on one or two

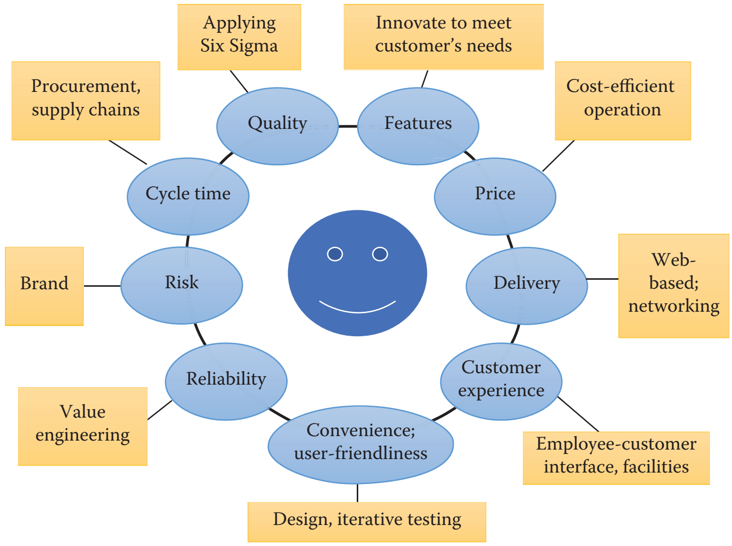

FIGURE 10.7
Nine dimensions and foci of innovation.

dimensions that have been neglected by the competition. The following examples demonstrate the effectiveness of this innovation approach:

1. JetBlue Airways offers a better customer experience by having live satellite television, leather seats, and fashionably clad flight attendants.
2. The Home Depot Inc. focuses on the needs of "do-it-yourself" customers.
3. Kaiser Permanent offers comfortable waiting rooms, lobbies with clear directions, and large examination rooms for three or more people, and curtains for privacy to improve customer experience (Nussbaum 2004).
4. Cemex shortened the time window from 3 hours to 20 minutes for delivering ready-to-pour concrete by utilizing global positioning systems (GPS) and computers in its fleet of trucks.
5. MinuteClinic locates its kiosks in stores such as Target and CVS to offer a menu of services to diagnose about 25 straightforward ailments, including strep throat and pinkeye. The nurse practitioner who staffs the kiosk can reliably diagnose the conditions in less than 15 minutes and write a prescription that the customer can fill in the in-store pharmacy. The value dimensions emphasized here are customer convenience and speed.
6. Starbucks offers a pleasant environment for conversation, reading, or relaxation, even though their coffee sells at $4.00 a cup.

When innovating along the value dimension of service features, it is important to understand the real needs of customers. Services that incorporate excessive performance features may overshoot the customers' needs, while demanding high prices could lead to poor marketplace performance. Scaling down the service features oftentimes reduces the price and meets a greater majority of lower-strata customers. Intuit was successful in simplifying its Quicken product to better fit the needs of small business customers and scored a great success in the marketplace.

10.5.3 Best Practices in Managing Creative People

Companies have many types of resources, such as raw materials, logistic systems, and political influence, but the most valuable one among them is creative capital. Creative capital is embodied in creative thinkers, who pioneer new technologies, give birth to new industries, and power economic growth, and in the relationships built between these thinkers and others such as customers, suppliers, and sales and support staff. This creative class is said to make up about one-third of the U.S. workforce (Torr 2008).

Over the years, SAS Institute, a software development company located in Cary, North Carolina, was able to develop three principles for managing such a creative class:

Employees' minds are stimulated by increasingly challenging work, attendance at professional conferences, opportunities to author and publish journal articles, the use of updated tools, and the financial support for additional training. Hassles are minimized based on employee surveys. Various on-site benefits are made available (day-care center, basketball court, exercise room, college advisement services, home-care aids, dry cleaning, haircutting, auto detailing, and others). Allow a flexible time schedule for employees.

To spark creativity, managers ask a lot of questions, bring groups of people together to facilitate the exchange of ideas and spur innovations, and procure the materials and tools needed by employees. Since managers also do hands-on work, they earn the respect of technologists. There is no penalty for making honest mistakes, as experimentation is crucial for breakthroughs.

The company tracks and organizes customer inputs and suggestions that are obtained through its website and phone lines, its annual web-based SASware ballot, and its annual users' conference. SAS software developers, consultants, and technical support staff interact with customers, learn their future needs, and invent new solutions for such needs.

Separately, Van Veen et al. (2015) emphasize the customer-centric research to promote innovations based on knowing who the customers are and what they want, by establishing a deep relationship with core customers, and then extending the number of customers beyond the core and further to new ones. In so doing, companies gain knowledge that is often opaque to competitors, promote employees' loyalty and reduce turnover, and attain innovations that add true value to the companies.

Example 10.4

Creativity needs to be encouraged by management. However, many companies take steps that unintentionally kill creativity. Name a few of such practices that discourage employee creativity.

Answer 10.4

Creativity is known to be affected by three components: (1) expertise, (2) creative thinking skills, and (3) motivation. Expertise and creative thinking skills are generally a part of individual capabilities, which are not readily influenced by management practices. Managerial practices have an impact on motivation, both the extrinsic and intrinsic kinds. There are a number of ways that management could inadvertently demotivate individuals to become creative (Amabile 2009):

1. Not matching people with the right assignments that utilize their expertise and skills, and stretch their abilities.
2. Failure to define project goals clearly and change them often. Leave no freedom for the individual to select methods to accomplish specific project objectives.

Autonomy around work processes fosters creativity and enhances intrinsic motivation.
3. Impose fake deadlines or impossibly tight ones and constrain resources needed to pursue creativity.
4. Set up teams with members who do not have diversified experience and expertise, do not collaborate well, and do not build trust among themselves.
5. Lack of positive managerial encouragement (e.g., remaining silent when outcome is good, taking a long time to evaluate outcomes, and creating an atmosphere of fear by criticizing failures).
6. Demonstrate no role models to promote all three creativity components.
7. Not fostering an organization-wide policy of information sharing and employee collaboration.

Example 10.5

In today's highly competitive marketplace, companies are striving to be customer-focused. In addition, many of them pursue open innovation strategies to create services that are useful to future customers. If you were in charge of turning customer input into innovation, how would you proceed?

Answer 10.5

Soliciting input from customers to foster innovation is indeed important for many companies that want to benefit from their customers' understanding of their future needs as well as their insights regarding new ways to satisfy such needs.

Simply asking customers what they would like to see in new services may not work. This is because most customers have a limited frame of reference and only know what they have experienced. They are not in a position to externalize what they do not know about emergent technologies, new materials, and the like. Furthermore, some customers may merely recite the missing features that other service providers already offer. Following such advice will lead to incremental development of "met-too" services. The service ideas of "lead users," those who have an advanced understanding of a service and are experts in its use, may be of limited general appeal, because they are not the average users. Customers may in fact not always welcome "new and improved" service features and functionalities. It is well known that vendors continue to upgrade the versions of their software with new features that most customers do not need but are forced to buy. An industrial survey indicates that customers typically use less than 10% of the software's overall capability. Innovation along this strategy creates resentment among customers. However, there is a methodology for capturing customer input that could be conducive to corporate innovation (Ulwick 2005).

The company should lay out the underlying process or activities associated with a service (e.g., a specific medical procedure) and hold interviews with a diversified set of customers who can judge the value of the service from the cost standpoint.

Appoint a moderator who could focus the customers on the underlying processes, not on the solutions of a given service. Ask customers to specify the improvements needed for each step in the process, the reasons for wanting such improvements, and the respective quantitative measures (time, number, frequency), so that the outcome statements can be used later for benchmarking, competitive analysis, and concept evaluation. In general, it may take three 2 hour sessions to complete such outcome-based interviews.

The company organizes the outcomes and asks customers to rate them for relative importance and satisfaction.

The outcome may be used to jump-start innovation by identifying new areas for service development, updating market segmentation, and defining a desirable competitive position for the company.

The key novelty of this approach is to ask customers for the new value or benefit they would like to see (not to name specific solutions). Then, the company develops solutions in specific forms that offer the desirable value to them.

10.5.4 Additional Guidelines for Managing Innovations

Established companies are known to encounter problems in pursuing breakthrough innovations. These problems are typically related to company culture, business practices, and management mind-sets.

Built on the business case of Analog Devices Inc., Boston, Massachusetts, Govindarajan and Trimble (2005) suggest three specific guidelines for established companies to succeed in bringing new innovations to market: (1) forget, (2) borrow, and (3) learn. Companies need to forget the old, albeit successful ways of doing business, to borrow from within the needed capabilities and resources to support the new innovative ventures, and to learn new ways to overcome uncertainties through careful planning.

When managing the development of a new service innovation, it is also important to assess the status of the critical complements that are required to bring value to the marketplace (Adner 2009). Offering a Ferrari in a world without gasoline or highways will not lead to marketplace success. Besides assessing the risks of developing the target service itself, companies must coordinate with complementary innovators and align all value chain partners to deliver the expected service performance in time.

10.5.5 Protection of Inventions and Innovations

Inventions and innovations need to be properly protected. They form valuable intellectual properties, which strengthen the relative competitiveness of the enterprise.

10.5.5.1 Types of Intellectual Properties

Intellectual properties, including innovative ideas, may be protected by (1) trade secrets, (2) copyrights, (3) trademarks, and (4) patents.

Trade secrets are valuable insights, work procedures, methodologies, know-how, or design that the inventors keep secret in order to realize competitive advantages. Copyrights protect the works of authorships (e.g., text, drawing, music, and video), fixed on a tangible medium (e.g., paper or CD) and are in effect for the duration of the author's life plus 70 years. Trademarks are graphic symbols that indicate the source of goods or services. They remain in effect as long as they are being used by the trademark's owners.

Patents are contracts between the inventor and the government. Inventors are required to disclose their novel ideas in details (e.g., composition of matter, process, products, or improvements) so that society at large will benefit from such novel and nonobvious ideas in the long run, in exchange for the right to exclude others from making, using, selling, offering for sales, or importing the invention into the United States for 20 years, measured from the date of patent filing.

10.5.5.2 Patents

Filing for a patent application is usually proceeded by an evaluation of (1) IP strategy, (2) novelty—patentability, and (3) commercial value. Inventors (and their employers) may pursue an offensive, defensive, or spoiler IP strategy. An offensive strategy is one in which patents are sought to carve out a new product/service domain for generating revenues from a new market segment. A defensive strategy, on the other hand, focuses on protecting the inventors' own core competencies from being encroached by competitors. The spoiler strategy is one in which patents are filed to prevent competitors from applying certain novel matter, process, or design, even though these areas are of no direct commercial interest to the inventors.

The issue of novelty is typically addressed via a patent prior art search. Internet sources such as the U.S. Patent & Trademark Office (USPTO) and the European Patent Office (EPO) are quite convenient for inventors to access. To be patentable, ideas must be novel, nonobvious, and useful. To be nonobvious, the ideas should not have been obvious to persons having ordinary skills in the art. Showing the circumstances in which applying the ideas at hand could generate unexpected failures is a good way to demonstrate the idea's nature of being nonobvious. Commercial value is generally a very important decision factor for filing a patent, as related to the alignment with corporate strategy, compatibility with current product/service offerings, and other such considerations.

A patent is a written document, which consists of the following sections: (1) background of the invention, (2) summary of the invention, (3) brief description of the drawings, (4) description of the invention, (5) claims, and (6) abstract. Inventors supply materials, data, and information, which are then absorbed into all sections. Claims are usually prepared by patent lawyers.

Claims represent the most important part of the patent. Using legal language, claims describe the specifics that inventors could enforce to exclude others from practicing the inventive contents comprising composition, process, product design, or improvements. Inventors try to prepare claims in a scope as broad as possible, whereas U.S. patent examiners strive to make the scope of the claims as narrow as possible.

A formal patent application represents a costly and time-consuming endeavor. As an alternative, inventors may first elect to file a provisionary patent with the U.S. Patent Office in order to retain the right to file a formal and detailed patent within one year of the original filing date, the earliest priority date. Provisional patents are useful to some inventors, who wish to preserve the priority date so that they may negotiate with potential users and explore the commercial value of the invention during this one-year period, and then decide if a formal patent application should be filed.

To facilitate the filing of patents in foreign countries, inventors may elect to file a patent cooperation treaty (PCT) registration within one year of the original priority date. They can then follow up with the filing of actual patents in any of the 139 signatory countries that participate in this system. The PCT system does not offer patents, as patents must be granted by the individual countries or regions (such as the European Union).

10.5.5.3 Public Disclosures of Potentially Novel Ideas

Inventors must pay special attention to the rules regarding public disclosure. Public disclosure is the practice of one of the following: filing a provisionary patent application, publishing papers in conferences, defending theses in open sessions, discussing ideas in departmental meetings, submitting abstracts of grant proposals to funding agencies, describing ideas in web pages, and others. If there has been no public disclosure of the patentable ideas before filing a U.S. patent, then the inventor has one year to file patent applications for protecting the same ideas in foreign countries. However, if a public disclosure has been made prior to filing a U.S. patent, then the inventor can only file foreign applications to protect the same ideas within one year of the public disclosure. It is thus very important to not disclose potentially patentable ideas to anyone.

10.5.5.4 Documentation and Inventorship

There are strict rules for establishing the concept of the patentable idea. It is generally recommended that bound notebooks with continuously numbered pages are used to document the novel ideas conceived, the date of idea conception, and the names of the inventors involved. This page must be signed by all inventors and cosigned by a witness, in order to be legally acceptable.

Whether or not all the inventors who sign such pages are a part of the eventual inventorship of a patent depends ultimately on the claims the patent contains. Inventors whose ideas form the basis of at least one of the claims in the patent are co-inventors. All co-inventors have the same rights to make use of a granted patent (e.g., selling, enforcing, offering license, creating joint ventures, and signing codevelopment contracts), without the consent of the remainder co-inventors, unless the rights issue is clarified and agreed on by all co-inventors before the patent applications.

10.5.5.5 Safeguard Against the Loss of Intellectual Properties

One frequently encountered problem when marketing novel products/services to emerging economy countries is how to effectively prevent the loss of the intellectual properties. Many companies are known to achieve some success by applying the following tactics:

1. When exporting hardware that requires the use of software, choose to have the hardware designed and manufactured in one country and the software in another.
2. Sell and market the product/service of an older version, and not the most innovative ones.
3. Screen all employees based on ethics.
4. Require all company employees by contract not to work for competitors within three years of leaving the company.

10.6 Selected Innovation Practices in Industry

10.6.1 Innovation in Communications, Financial, and Technical Business Services

Based on a study of Canadian service industries in 1998, several innovation strategies are common among the services industries of communications, financial services, and technical business services: (1) focusing on existing customers and service quality to maintain or increase market share; (2) treating customers as the key sources of innovation ideas; (3) emphasizing the use of copyrights and trademarks, instead of patents, to protect intellectual properties; (4) de-emphasizing the drive to improve productivity or employee skill level (Gellatly and Peters 1999).

Companies in the service industries face different pressures from the marketplace. As a consequence, they tend to drive their innovation processes differently. Innovation is pursued for different reasons, in different ways, and to meet different industry-specific objectives.

1. The communication industry perceives as its major threat the advancements in production technologies and regulatory constraints. They orientate their innovation strategy toward the use of high-quality suppliers and the acquisition of new technologies. They focus on improving service quality and reliability. They get innovation ideas from suppliers and the availability of new technologies (e.g., conversion to fiber optics and digital-based technologies). They regard legislative restrictions (e.g., restricting the nature and content of services) as an innovation obstacle to overcome. In this industry, competition is viewed as less intense than in others.
2. The financial services industry regards as a major uncertainty the service substitutability by consumers and price competition. They understand the need of customizing service, and of being price-competitive. Thus, they focus on treating their employees well (compensation plans, skills development) and hiring qualified staff. As a result, their innovation strategies are focused on reducing labor costs, speeding up delivery, protecting know-how by trademarks, and getting innovation ideas from their competitors.
3. The technical business services industry faces uncertainties in predicting the future actions of customers and competitors, and dealing with product obsolescence. They need to emphasize service quality and customer experience. They are typically oriented toward technology development and refinement through in-house R&D. Their innovation drives tend to concentrate on service flexibility to diversified customers, as well as service quality, adaptability, user friendliness, speed of delivery, and accessibility. In-house R&D is a major source of ideas for innovation, which are typically protected by patents. Companies in this industry may face some major hurtles related to financial and manpower resources.

When planning for innovation strategies, it is thus important to consider the main market pressure the industry is under in order to maximize the benefits derivable from the innovative efforts.

10.6.2 Innovations in Insurance Industry

The insurance sector is generally known to be a slow adopter of new innovations, such as the Internet and wireless data communication devices. This is partly due to its business nature of being low volume and low frequency. However, the development of IT technologies, globalization, customers' demand for transparency leading to insurance products commoditization, and industrial consolidation will induce more changes in the future. Besides cost control, the insurance sector is expected to embrace new business designs, and to promote offerings, marketing ability, product/service distributions, and risk assessment.

Examples of some of these new innovations in the insurance sector include:

1. Progressive Insurance, Mayfield Village, Ohio, introduced the immediate response claims service, which was later revised to become immediate response vehicles, to enable an adjuster to write a check on the spot at an auto accident, thus lowering the cost and creating a positive customer experience. Oftentimes, the agent is able to impress the other party in the auto collision such that he or she becomes a progressive customer.

   Progressive launched the first insurance website, to offer online policy purchasing in real time and to pilot *usage-based* insurance via GPS and cellular data modems. Customers pay insurance premiums that are based on the actual behavior of the driver.
2. Components of a new insurance application architecture (IAA) were developed by IBM to promote the creation of the next-generation insurance applications. These components make use of the service-oriented architecture to connect hardware and software elements into an underlying enterprise service bus, which fosters the development of new insurance business designs, strategies, and opportunities.
3. Jefferson Pilot Financial, Greensboro, North Carolina, and Grange Mutual, Columbus, Ohio, started supporting their distribution channels and reducing the barrier to using their systems. They developed web portals for their agents and broker customers.
4. Nationwide Insurance, Columbus, Ohio, connected several data sources to create a single view of its customers, thereby improving customer experience and reducing processing errors.

10.6.3 Innovations in Food Industry

The food industry is increasingly adopting new technologies to reduce cost, improve operations, and raise customer satisfaction (Stewart and Martinez 2002). Wal-Mart is known to have pioneered the practices of linking across the supply chain and using information technology to respond more promptly to the marketplace. In 2001, the company became the nation's largest food retailer.

Several examples of innovations in the food industry include:

1. *Efficient consumer response (ECR)* was launched by the grocery retailers and industry trade associations in 1992 to (1) manage the mix of products on retail store shelves and increase sales and product turnover, (2) reduce out-of-stock percentages, (3) eliminate inefficiencies between supply chain partners and minimize problems leading to inefficient trade promotions, and (4) increase the success rate of new food products.
2. *Efficient foodservice response (EFR)* was established by the food service industry in 1996 to promote the use of standard product identification codes. Bar coding produces 1 error in 3 million, whereas manual key entries register 1 in 300. Tyson Foods bar codes nearly 100% of its 4000 products.
3. *eFS Network* was created in July 2000 by food industry leaders such as McDonalds, Sysco, Cargill, and Tyson Foods to increase an Internet-based, industry-wide marketplace for food service companies.

To induce sales, stores apply special tactics to cause shoppers to stay longer, and walk slowly through the aisles. They use smells and sights to trigger shoppers' appetite. Some of the well-known tactics the stores use include:

1. Candy and magazines are placed at the checkout counters so that bored, cranky, and hungry shoppers are tempted to grab them.
2. Breakfast cereals are located directly across from the candy section, so that kids can check out the candy while Mom is filling up the cart with cereal.
3. Sugary cereals for kids are always on the lower shelves, at a child's eye level and within reach of little arms.
4. Most folks assume that the items located at the end of the aisles where shoppers do their U-turns into the next aisle are full of sales items. This is usually not the case. That very valuable real estate is full of special items, as suppliers pay the stores more to have their merchandise put there.
5. Items are regularly moved throughout the sores so shoppers walk around longer and buy more stuff.
6. New products are placed near the top-selling items in order to encourage shoppers to try them.
7. Shoppers are kept longer in stores by offering services such as a coffee shop, cafeteria-style buffet, pharmacy, photo processing, and others, while playing slow music.
8. Shoppers' senses are attracted by placing items with mouthwatering smells, such as cookies or rotisserie chickens, at the store's entrance section. Food samples are used to trigger shoppers' appetite.

Studies have shown that as a consequence of applying such insightful tactics, shoppers usually buy 40% more than what they set out to buy.

10.6.4 Major Hurdles to Innovations in Health Care

The cost of U.S. health care is around $2.2 trillion (17% of GDP) per year, being among the highest in the world. Hospital activities account for $400 billion of the excessive costs. Still, about 300,000 people have died due to hospital "medical errors" in the past few years. Third-party pay providers control reimbursement and favor physicians who follow "recipes" that are established by the innovation-killing "peer reviews" process.

Duke University Medical Center is known to have developed an innovative program for people with congestive heart failure. In only one year, the program reduced costs by 40%, substantially improving patients' health that hospital visits and usage plummeted. As a consequence, the hospital's income dropped accordingly, as the providers (insurance companies) only pay for treating sick people. The third-party pay providers in our current system do not reward innovations in health care (Herzlinger 2007).

Entrepreneurs avoid health-care delivery because providers (governments, insurance companies) set prices, specify procedures, and define the types of patients to be covered. To change the system in favor of innovation, we need a consumer-driven health-care system in which consumers can reward new and innovative developments that improve health.

Example 10.6

Innovations are of fundamental importance to any company. However, innovations entail risks. Management must be prepared to anticipate risks and devise ways to mitigate them. What kind of strategies should a company consider to manage risks related to its innovative pursuits?

Answer 10.6

In general, management needs to follow the following general principles to pursue service innovations: (1) define a clear challenge in terms of a customer need (not a business need) that is worthy satisfying; (2) identify a process to pursue innovations that include multidisciplinary participation and sources of cutting-edge ideas; (3) favor concepts that combine multiple elements of innovations (e.g., business model, IT platform, and channel) to increase impact and distinctiveness; and (4) apply techniques and structures that counterbalance the forces of risk aversion.

Risks are inherent in service innovations. Rao (2005) suggests a few "best practices" to mitigate them:

1. Remove the naysayers in leadership positions
2. Make go/no go decisions by determining if the company can survive the worst-case outcome
3. Make exploratory funds available for trying new concepts
4. Motivate innovation teams by inducing competition
5. Create a special environment for allowing the exploration of new opportunities far afield from the main business line (e.g., IBM's Watson Health)

10.7 Conclusions

In this chapter, we first discussed the creative process and several creative thinking strategies to promote the generation of new ideas that precede innovations. We then elaborated the fundamentals in innovations (value chains, processes, keys), and the strategies and practices of managing innovations (organization, business dimensions, best practices, examples, guidelines), followed by innovations examples in selected sectors.

The examples of service innovations discussed in this chapter represent the good results of an innovation drive of the service industry. The specific cases discussed illustrate the various new opportunities that remain open for additional innovations in technology, business model, and/or process. Much more is sure to come.

Strategic differentiation sets any enterprise apart from its competitors in the marketplace. It impacts its long-term potential of generating sales revenue, the top line, in a sustainable way. In the absence of any strategic differentiation, the enterprise would offer products/services only of a commodity type, which do not confer competitive advantages. The objective of this chapter is to lay the basic foundation that should enable STEM professionals to start developing innovations. The sooner they acquire the essential skills and understanding in relation to innovations, the sooner they will become productive in making creative contributions to their industrial sectors. There is a significant opportunity for those who are willing and technologically able, to innovate in the service industry.

STEM professionals and leaders are advised to constantly nurture the following skills in order to promote strategic differentiations:

1. Capabilities of thinking creatively (e.g., employing the DeepThink strategies) in order to generate creative products/services ideas.
2. Constantly on the look out for new technologies, supply chains, business partnerships, and domain expertise, whose inclusion could inspire the generation of

newer upgraded products/services elements (core and supplemental), thereby enhancing their own competitiveness in the marketplace.

3. Basic managerial skills of planning, organizing, leading, and controlling regarding projects, teams, programs, technologies, and other resources, which are essential in any competitive and customer-centered enterprise.
4. Skills in dealing with financial accounting, technology assessment, and marketing management, so that financial viability, technical feasibility, and marketplace acceptance of a new product/service idea can be readily determined.

Progressive enterprises are advised to constantly attract innovative workers with the abovementioned capabilities, as they will become great contributors to help pursue the all-important innovation pathway to vault them ahead of their competition.

QUESTIONS

1. The 3M Company is a diversified technology company that aggressively pursued innovation. What is unique about the innovation strategy of this company?
2. What are the relationships between creativity and innovation?
3. Discuss the steps of the inventing procedure commonly followed by inventors.
4. Problem solving is a fundamental skill that all systems service engineers and managers must possess. Its use in industry is rather frequent. What steps should be included in a generic problem-solving process?
5. STEM professionals need to access new ideas from time to time. Which sources should they tap into in order to obtain new ideas?
6. All enterprises need creative employees to attain strategic differentiation. These creative employees need to be properly managed. What are the useful guidelines for managing creative people?
7. Creativity is a highly desirable personality trait many enterprises are looking for in their new employees. STEM professionals and managers are special people who possess the basic training in engineering/scientific disciplines with an inclination toward entrepreneurship. What in your opinion are the important characteristics of such a creative person?
8. There are many techniques used in engineering to promote creative thinking. STEM professionals and managers should apply them whenever appropriate. Name some of these creativity methods in engineering.
9. The performance of any company can be promoted by specifying a set of metrics that can be readily measured and then monitoring them rigorously. To promote the creativity and innovation of a service enterprise, one needs to define a set of metrics for determining its innovative performance. Name a number of such metrics.
10. Creativity and innovation will usually result in some changes to be introduced into the organization, such as a new production process, new marketing strategies, new procedures of offering customer supports, and others. Not everyone likes changes and some will in fact resist them. STEM professionals and managers need to be prepared to manage changes. Explain the principal reasons for resistance to change in organizations.

11. When managing innovation, STEM professionals and leaders might be able to take advantage of specific practices that were beneficial to other managers in the past. Name a few useful lessons about managing innovation that can be gleaned by scanning the applicable business literature.
12. The management of innovation demands a broad and balanced approach. What are the factors deemed to be critical for achieving success in innovation management?
13. STEM professionals and leaders face many challenges when managing innovation. What are some of these top challenges in managing innovation?
14. Marketing and innovation are said to be two significant competencies of any enterprise.

    a. Explain, why these two competencies have been singled out as significant?
    b. Why would those engineering managers, who possesses demonstrable skills and insights in both of these competencies, be perceived to be particularly valuable to corporate enterprises?
    c. What specific activities could an engineering manager, who possesses demonstrable skills and insights in both of these competencies, actually pursue in order to maximize the value that he or she creates for his or her employers?

15. The topic of cross-function teams was discussed in this text. It was postulated that nowadays teams are the most appropriate organizational structure for managers to deploy in promoting and realizing innovations, be it in conjunction with new service/product development, new process improvement, service design, problem solving, or other such efforts needed on a continuous basis to meet the challenges of the future. In fact, without innovation, companies will soon cease to have long-term profitability in the absence of relative competitiveness in the marketplace. Thus, it is imperative that future managers must know how to lead teams effectively. Explain what is required for teams to become innovative and to be able to create synergies that are otherwise not readily attainable.

Appendices

Appendix 10.A: DeepThink Question-Based Prompts

1. *Delve*: To delve is to dip deeper down to the component and subcomponent levels of an idea/concept in order to exploit the interfaces therebetween, and the roles and value contributed by these parts. Ask the questions:
    a. Can some of these components be removed without affecting the value of the whole idea? What is not necessary?
    b. What might be missing? What could be added to heighten the idea's novelty?

c. Can the components' topology be modified to achieve more novelty and uniqueness? Are there other patterns, layouts, or sequences of processing that can be applied to these components to make the idea better?
d. What other problems may lie inside the problem at hand?
e. Can we separate the various parts of the problem and look closely at the relationships between these various parts?

2. *Envision*: To envision is to think divergently and to project an idea forward into the future. Ask:
   a. Do I make the idea more novel, if I project it forward into different environmental conditions (e.g., reference point in time, physical environment, user community, or technological conditions)?
   b. How can I change the level of abstraction (e.g., from components to systems, and from local to global) to obtain new perspectives regarding the possible alternative use of this concept?
   c. Which new insights may be acquired here? How can these insights be layered upon others to bring about new ones?
   d. Which open-ended questions would help promote further in-depth discovery?
   e. What new possibilities can I project forward from the idea at hand?
   f. What "future" states may be foreseen that differ significantly from the "current" state?

3. *Exchange*: To exchange is to replace or swap components in order to add value. Ask:
   a. What if this part is replaced by that? Would I add more value, if I use this part instead of that?
   b. Is there more synergy, or do I add more novelty to the idea, if this part is swapped with others?
   c. How can this idea be nested inside others to intensify the idea's novelty? Which ideas outside of my field could I incorporate?
   d. Are there new ways of using this idea? Are there other uses for this idea, if it is properly modified?
   e. Which new insights could I discover, compile, or extract, to magnify the novelty of this idea?

4. *Perturb*: To perturb is to seek novelty improvement by slightly modifying the concept's attributes and features. Ask "what-if" questions as follows:
   a. What if I challenge the basic underlining assumptions (major driving forces) and constraints (time, power, people) to exploit new possibilities?
   b. Which nuggets of wisdom (e.g., business trend, scenarios, rules, application practices, ways of looking at the available knowledge, reasons for something what works, and how analogies work in different contests) can or should be replaced, modified or reapplied, in order to improve the idea's novelty?

   c. What if I do the opposite of what others might do, in order to exploit what might happen?
   d. "How can I improve the novelty of a concept by changing one of its features (e.g., rules, procedure, focus, plans, process, marketing, approaches involved, knowledge nuggets, sequence of operations, time line, physical size, usage complexity, customer accessibility, degree of customization, or value to customers)?
   e. How can I economize by reducing, streamlining, omitting, miniaturizing, or deleting something in order to upgrade the concept's novelty?
   f. What can be magnified, extended, exaggerated, or overstated to enrich the novelty of this concept?

5. *Transpose*: To transpose is invoke lateral thinking by looking at the same concept or issue from several different perspectives. Ask:
   a. What do I gain as new insights for possible betterment, if I view the concept at hand from the viewpoints of producers, customers, marketers, or competitors? What if I reverse the roles?
   b. How can we help customers to identify what they want to buy?
   c. What are the opposite views to those that are current and predominant regarding this concept? How can I make use of these opposite views to see new opportunities for adding novelty to the idea?
   d. May this idea be reframed in a new way to uncover unexpected new possibilities?
   e. What would happen, if I did the unexpected?
   f. What can be learned if a higher-level perspective is adopted—instead of looking at individual trees, glancing at the forest?
   g. How can I invigorate the customer's acceptance of this service idea?

6. *Harness*: To harness is to discover and redeploy the wisdom contained in other ideas for new circumstances. Ask:
   a. What could I adapt from ideas that were used before in different prior applications?
   b. Which ideas outside of my fields could I harness and adopt for use in the present situation?
   c. What analogies may be drawn here? How can a technique in one area be applied to a new domain?
   d. Which other ideas does this concept suggest?
   e. What else is like this?
   f. Which different contexts can I put my concept in?

7. *Integrate*: To integrate is to combine ideas and concepts in different contexts to form new ones. Ask:
   a. How can I selectively combine things (e.g., rules, ingredients, materials, processes, peoples, procedures, power, places, or approaches involved) to cultivate the idea's novelty?

b. How would this concept work when merged or nested into another one?
c. What can be combined (e.g., unrelated ideas, goods, services, work processes, materials, articles, units, purposes, assortments, applications, and business models) to augment the novelty of the idea?
d. What synergistic combinations could be conceived?
e. What could I adapt (e.g., part of other processes or ideas)?

8. *Nurture*: To nurture is to modify and adjust separate and unrelated concepts/ideas to form something new. Ask:
   a. How could I modify unrelated concepts and make them compatible to one another, so that they together form increasingly novel ideas?
   b. Could I find opportunities of making these ideas more compatible to one another, and hence potentially more novel, by changing some of their respective features (e.g., meaning, color, motive, sound, focus, attributes, reward schemes, shape, name, plans, process, or marketing)?
   c. What would it take for me to make these unrelated concepts compatible to one and other?

9. *Knock*: To knock is to knock down limitations, negative driving forces, assumptions, and conventional wisdom, which may have constrained the value of the concept. Ask:
   a. How can the idea's novelty be enhanced by relaxing some of the existing assumptions, constraints, negative driving forces, and other barriers and restrictions associated with the idea?
   b. Which are the present resources and technologies that are currently constraining the novelty and value of the concept at hand?

Appendix 10.B: Selected Examples of Creative Ideas That Demonstrate the Use of DeepThink Methodologies

1. *Delve: Can the components' topology be modified to achieve more novelty and uniqueness? Can we separate the various parts of the problem and look closely at the relationships between these various parts?*

   George Vance of Rock Hill, South Carolina, invented the idea of a seat partition with a deformable frame aiming at "reducing the interaction" between two kids who sit next to one another in the back of a car and keep them under control. By applying the strategy of "divide and conquer," this allows for a quieter atmosphere in the vehicle, so that the driver can better concentrate on driving.

2. *Envision: What new possibilities can I project forward for the idea at hand?*
   a. *What "future" states may be foreseen that differ significantly from the "current" state?*

      In 1962, J. C. R. Licklider of Massachusetts Institute of Technology, Boston, envisioned a globally interconnected set of computers through which everyone could quickly access data and programs from any site, the Galactic Network concept. Of course, having a vision is necessary but not sufficient for creating value. A large number of scientists worked on innumerable individual enabling technologies (e.g., packet switching, communication protocol, and spanning tree algorithm) to develop ARPANET (Advanced Research Projects Agency NETwork), the first working version of the Internet in 1969. ARPANET was successfully demonstrated to the public in 1972, including the use of e-mails. Having a vision into the future is the key here.

By envisioning a new service for local customers, who are not adequately being served by traditional car rental companies, Zipcar was invented by Robin Chase. This new service allows its fee-paying members to make reservations, pick up a car at GPS-designated locations, drive away, return, sign off, and get bills automatically. The cars are usually parked at lots near bus stations, so that local customers, who do not own cars or are in need of the service of a second one, can get there by public transportation. This rental service is particularly suitable to local customers who want the use of an automobile for a short period of time. This car-sharing model is enabled by three technologies: high-speed Internet, mobile broadband, and GPS. If desired, the customers fill up the tank using a special charge card available in the car. A daily or hourly rate is charged, including insurance, gas, maintenance, and 24/7 roadside assistance, with a limit of 180 miles per day. The American Automobile Association estimated that owning a car costs about $8000 a year. Zipcar customers could save $600 per month. Each shared car takes up to 20 cars off the road and they could wring out 50% of carbon dioxide emissions. While the car-sharing concept practiced by Zipcar has been novel, the company was eventually absorbed by Avis in January 2013 for $500 million.

Extending the car-sharing concept further, Get Around and RelayRides set up to rent out privately owned cars to registered renters on an hourly basis, while providing insurance, billing services, and roadside assistance. This service model is attractive to those car owners who want to see a better utilization of their otherwise idling cars.

b. *What new possibilities (e.g., applications) can I envision for the idea at hand?*

In 1974, Arthur Fry of 3M Company looked closely at the weak glue invented by Sheldon Silver, another 3M engineer. The weak glue could not hold two pieces of paper together. On a Sunday morning, Fry sang in the church choir and wanted to put little pieces of paper in the hymnal to mark the songs he was supposed to sing. The pieces of paper often fell out, forcing Fry to frantically look for the right page. During a particularly tedious sermon, Fry suddenly realized how he might use that weak glue to contrive a reusable bookmark, which became the most widely used office product in the world: the Post-it note. A new product was thereby invented.

c. *What new possibilities (e.g., satisfying a new marketing demand) can I envision from the idea at hand?*

There is a big shortage of family doctors in the United States, partly because current insurance policies limit the reimbursement dollars received by family doctors. The situation is expected to become worse in the future, as many young medical students elect to go into specialty training, avoiding becoming general practitioners. Furthermore, all emergency rooms of local hospitals are typically very crowded, resulting in hours of waiting time for patients seeking emergency care. An inadequately served market niche was thus identified in need of emergency care by a variety of families.

Immediate Care sets up local clinics to care for most non-life-threatening injuries and illnesses (e.g., sprains, strains and fractures, cuts and lacerations, animal and insect bites, cold and flu symptoms, upper respiratory infections, and minor burns) as an emergency room alternative. It is open until 10:00 p.m. most days during the week and 8:00 p.m. on weekends. This chain carries the gold seal of approval from the Joint Commission and accepts most insurance plans. Urgent Care clinics are manned by off-duty doctors and nurses, daily until midnight, to care for patients under the age of 21. Family Care Medicine is another such group practice that offers competing medical care services. MinuteClinic are nurse-managed kiosks, which provide diagnosis of and prescription for two common ailments. They become available in shopping malls to compete against the busy doctor's practices.

These novel business models are formulated to address an identifiable market need, which is not being satisfied by the current medical practice.

3. *Exchange and integrate: Exchange: To swap new concepts with what is currently available. Integrate: To combine ideas and concepts in different contexts to form new ones.*
   a. *What can be combined to form a new novel concept?*

      Johannes Gutenberg invented the printing press by having coupled the flexibility of a coin punch with the power of a wine press, thus enabling the production of books, which spread knowledge and ideas throughout the world.

      Trevor Bayliss invented the clockwork radio, which can be mechanically wound up by hand. This is particularly useful to people living in an area where there is no or little electricity.

      The Segway Personal Transporter combines the technologies of battery, gyroscope, electronic control, and electrically driven scooter to contrive a new device, which offers transportation service to a user in a standing-up position.
   b. *What can be added to its marketing elements (e.g., physical evidence, delivery, people—Figure 2.8) to augment the novelty of the idea?*

      Starbucks offers a pleasant environment attractive to its target customers, who want to enjoy coffee and a place to read, relax, or work. Its well-trained baristas serve as excellent conversation partners. It was a novel idea being different from its competitors by zeroing in on the service marketing elements of "physical evidence" and "people."

      A further extension of this idea is to have Starbucks shops inside Barnes & Noble book stores, so that customers may browse over a variety of books of interest while having a comfortable place to sit and enjoy food and drinks. Starbucks have also been added to some hospitals to serve the medical professionals and patients there.

      It is of course also known that the Hooter Restaurant chain applied the same concept of enhancing the "physical evidence" and "people" of its service environment by employing young attractive waitresses with shapely figures to serve food and drinks.

Progressive Insurance introduced the immediate response vehicle, which allows its adjuster to reach the spot of an auto accident, settle the claim, and write a check to its policyholder instantly. This service delivery mode lowers cost and builds a positive customer experience, as its policyholders avoid long waits related to paperwork and other administrative hassles.

Southwest Airlines does not assign seats. Instead, it requires passengers to electronically check-in within 24 hours of flight departure, receive a boarding pass that carries an assigned boarding number, and board the plane accordingly. The first 15–20 slots are typically reserved for passengers who are willing to pay an extra small fee. At each terminal gate, vertical signposts were erected to implement this sped-up boarding process, so that the same terminal gate may be used for more Southwest flights during the day, thus reducing the overhead charge for each flight. Furthermore, this process encourages passengers to arrive earlier at the gate, as they are in competition with other passengers for good seats. By modifying one part of the service delivery step, Southwest Airlines realized a betterment of customer experience, a shortening of gate time, and a reduction in operations costs.

4. *Harness: What analogies may be drawn here? How can a technique in one area be applied to a new domain?*

"The inventor has a logical mind that sees analogies," Thomas Edison said. In applying the thinking process of "analogies," one should try to remember certain ideas, actions, program steps, or technologies, which were known to us in other applications (e.g., other service offerings, other product organizations, and even applications in unrelated fields), but which could be applicable to the current project here. If so, by all means write it down and add them to the section. Using such "analogies" is a useful strategy for coming up with innovative ideas. In fact, applying a known idea, pattern, or relationship to a different field is one of the most commonly known pathways to creativity. The following three examples are noteworthy:

Nissan crash-avoidance technology mimics bumblebee instincts—the *American Free Press* (10/1/08) reported that "Nissan Motor Co. has tapped into an unlikely source of inspiration for technology to prevent car crashes—bumblebees." The BR23C (Biomimetic Car Robot Drive) "is a meter-high duckling-shaped robot with a sensor that recreates the highly complex eyes of a bumblebee," and "can detect an object up to two meters away in a 180-degree radius. It swerves away on wheels when a person or an object suddenly appears in front of it." The automaker "hopes eventually to put the technology into cars." Toshiyuki Ando, a Nissan engineer said, "The split second it detects an obstacle, it will instantly change direction by turning its wheels to a right angle or further to avoid collision. The whole process is to mirror what a bee does to avoid other bees. It must happen with the blink of an eye. 'Nissan' teamed up with researchers from the University of Tokyo to advance part of the system, which calculates the distance to an object and then sends the information back into the car."

Cannon copier drum design: A group of Cannon copier designers took a break to brainstorm, while holding cans of beer in their hands. One of them got the inspiration of making the copier drum, which represents 90% of the copier reliability problem, disposable. This is a good example of innovation by analogy, sometime accidentally.

Tough ceramics: Lawrence Berkeley National Laboratory mimicked the structure of the mother of pearl to invent a tougher ceramic. They applied the controlled freezing of suspensions in water of an aluminum oxide (alumina) and the addition of a polymer, polymethylmethacrylate (PMMA), to produce ceramics 300 times tougher than their constituent components.

Air-conditioning: Willis Carrier was waiting for his train to arrive. He was watching as the fog was rolling in across the platform. He realized suddenly that he could use the principles of fog to cool buildings. He invented the idea of cooling building using fog. This was an invention by analogy.

NASA mirror correction: The mirror of NASA's Hubble Space Telescope was found to have been ground improperly after the telescope was already launched into space in 1990, and brought about an embarrassing blurry vision to its users. NASA engineer James Crocker was taking a shower in a German hotel room and noticed the extendable shower hand, which could be adjusted to the user's height. Crocker made an analogy between this extendable shower hand and the myopic telescope and invented the idea of placing corrective mirrors on automated arms that would reach inside the telescope and adjust it to the correct position. The corrective optics space telescope axial replacement (COSTAR), which comprises 8 motors attached to 5 metal arms holding 10 coin-sized mirrors, was able to solve the telescope problem.

Velcro fastener: George deMestral noticed in 1948 that burdock burrs stuck to his dog's fur with tiny hooks. He borrowed this idea and generated the same effect artificially. Today, shoes and other objects are fastened with burr-like hooks and cloth-like loops.

Dyson vacuum cleaners are designed to remove dust from the airstream by centrifugal forces, analogous to that used in the cyclones for sawdust separation at sawmills.

5. *Nurture: What would it take for me to make these unrelated concepts compatible with one and other?*

Toyota invented the hybrid engines by modifying the international combustion engine, which burns fuel to cause a shaft to turn (in order to drive a car), and adjusting an electric generator, which uses the excess shaft power to produce electricity for a battery or withdraws power from the battery to operate the generator as a motor in order to turn the shaft. Working together as a unit, it realizes fuel savings, as the car is often idling at red lights or stuck in traffic jams on highways.

Fusion music is put together by merging together different music of the East and West. It offers something fresh to the listeners away from traditional concerts and adds to the globalization concept.

6. *Knock: How can the idea's novelty be enhanced by relaxing some of the existing assumptions?*

Who says that airline passengers should depart and return between two cities? JetBlue relaxes this conventional assumption by introducing a novel "all you can jet" pass for $600, which allows passengers to book an unlimited number of flights between any of its 56 U.S. destinations within a period of one month. For business travelers who plan to visit a number of cities quickly, such a pass may be ideal. This is similar to the business models of (1) all you can eat (cafeteria), (2) all you can exercise (fitness centers), (3) all you can drive (rental cars with no mileage limits), and (4) all you can read anywhere (Amazon's Kindle).

All households accumulate items that are not used frequently but are kept within reach. They take up valuable space and make their surroundings look cluttered. The Storage by the Box company challenged the assumption of having to keep such items locally at home and came up with the service idea of box storage at remote locations. Customers are persuaded to pack unused items in boxes and send these boxes via FedEx to a Chicago-based warehouse for safekeeping. The boxes are numbered and can be retrieved on demand. Customers are advised to take photos of the boxed items in order to facilitate their future retrieval. The company charges only for the space used, saving customers up to 60% on storage costs. This is one way of thinking outside of the box.

Shoes are typically packed in inexpensive cardboard boxes, which are easily damaged, nontransparent, and readily replaced. This assumption was removed by Shoebby, which makes their shoeboxes out of thin-gauge clear plastic sheets, so that their contents are easily recognized from a distance, thus facilitating a rapid selection by their users.

7. *Transpose: How can I invigorate the customer's acceptance of this service idea?*
   a. *How can we help customers to identify what they want to buy?*

      Wal-Mart built a knowledge base (e.g., social genome), which data-mines customers profiles from social media (e.g., Tweets blogs, Facebook messages, and You Tube videos) to identify consumption and then propose gift ideas to customers.

   b. *How can we encourage shopper traffic to retail stores?*

      ShopKick offers a smartphone application that utilizes closed-circuit store networks to recognize customers when they enter the store and reward them with in-store offers and "Kickbucks," which are redeemable points that customers collect. This system is being applied at Best Buy, Macy's, and Target.

   c. *How can we sell more by promoting users' self-expression and reaching customers' friends*

      Uniglo devised a web page to enable its customers to connect with one another. Customers could upload their photos while wearing the new Uniglo clothing to participate in contests, which are rated by other users. Naturally, they will also send the photos to their friends via a smartphone application, a free "word of mouth" advertisement for the company.

8. *Perturb, integrate, and transpose: Perturb: How can I improve the novelty of a concept by changing one of its features? Integrate: How can I selectively combine things to improve the idea's novelty? Transpose: How do I gain as new insights for possible betterment, if I view the concept at hand from the viewpoint of the customers?*

Economy-class passenges of long flights are known to suffer from having to sleep in an upright sitting position. Air New Zealand invented the idea of removing the arm rests and adding large flip up cushions that fill the space between three standard economy seats to create Skycouch, which provides a flat space of 156 cm long and 76 cm wide. It is priced at 2.5 economy seats, particularly attractive to families with young children. About 30 international airlines are said to want to license this new seat design in 2012.

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11

Ethics in Engineering Management and Workplace

11.1 Introduction

Recent corporate scandals published on the Internet have raised serious questions about ethics in the workplace, notably the cases of Enron, Global Crossing, Adelphia, Arthur Anderson, Tyco International, Gallon Insider trading, the Bernard Madoff Ponzi scheme, and others—all alleged to have falsified financial data or misused corporate funds. Steps have been taken by the Financial Accounting Standards Board (FASB) to tighten the financial audit guidelines for the future. Not too long ago, two top editors of *The New York Times* resigned because they had failed to rein in one of their staffers who had fabricated or plagiarized three dozen stories over a six-month period. Exposure of these cases in the news media causes public anxiety and apprehension. But the focus of the public's attention on ethics in the workplace should help motivate managers to avoid willful wrongdoing (Hosmer 2010; Ferrell and Fraedrich 2014).

As the markets in the new millennium become more dynamic and business relationships increasingly intertwined, opportunities for conflicts of interest and ethical dilemmas are likely to become more prevalent. This chapter addresses some of the issues and solution strategies related to ethics in business and engineering management (Parboteech and Cullen 2012; Trevino and Nelson 2010).

Recently, the Pew Research Center for the People and the Press in Washington, DC, conducted a survey, asking: "Would you say most business executives try to obey the laws governing their professions, or do they try to find a way around the laws?" Thirty-five percent of respondents said they obey the laws, 58% said they find a way around the laws, and 7% offered no answer. In terms of whose interests the companies put first, the survey identified a drastic difference between the public's perceptions of current practices and what they perceived the right emphasis should be. For example, current practices for top executives, stockholders, employees, and customers (regarding whose interests the companies put first), was 43%, 37%, 3%, and 5%, respectively. On the other hand, the perceived right emphasis for them turned out to be 3%, 14%, 31%, and 37%, respectively.

In a 2014 Gallup Poll, the public were asked to assess the honesty and ethical standards among professions. The top 11 ranked professions, in descending order, were (1) nurses, (2) medical doctors, (3) pharmacists, (4) police officers, (5) clergy, (6) bankers, (7) lawyers, (8) business executives, (9) advertising practitioners, (10) car salespeople, and (11) members of Congress.

There are numerous situations in which engineers and engineering managers may encounter problems with ethics. These situations include public safety and welfare, risks, health and environment, conflicts of interest, truthfulness, integrity, choice of a job, loyalty, gift giving and taking, confidentiality, industrial espionage, trade secrets, discrimination, and professional responsibility.

Generally speaking, there are both microethical and macroethical issues. In microethics, the focus is on the relationships among engineers and their coworkers, clients, and employers. In macroethics, engineers are concerned with the collective social responsibility of the profession in relation to, for example, product liability, sustainable development, globalization, and the impact of technology. Sustainable development refers to industrial practices that minimize harmful impacts on the environment while maximizing the efficiency of energy and material use. This chapter will address both types of issues.

In the research literature, two basic approaches are taken to handling ethical issues: addressing the general philosophy underlying a particular outlook, and examining specific cases to draw out lessons related to ethics. There are weaknesses in both approaches. The philosophical approach lacks a connectedness to the real-world environment, and thus produces no guidelines to deal with actual situations. On the other hand, the case-based approach produces only “school solutions” after the fact. These may or may not generate any useful lessons to be learned (Harris et al. 2013). Since there are a number of well-known cases related to ethics, this second approach is selected for use in this chapter.

Not all problems in ethics have practical solutions, just as not all product design problems have feasible solutions. Furthermore, as more and more companies pursue globalization, an additional concern is that what is “normal” in one culture may not translate acceptably to another (Brenkert and Beauchamp 2012).

In this chapter, the deliberations about ethics begin with basic definitions, followed by discussions about engineering ethics, which are then extended to business ethics. The chapter concludes with general guidelines on dealing with ethical issues.

11.2 Ethics in the Workplace

Ethics is important to corporations because companies with strong, positive overall reputations attract and keep the best customers, employees, suppliers, and investors (Bredeson and Goree 2011). These companies also avoid the trouble of litigation, fines, recalls, bankruptcy proceedings, and antitrust suits. Corporations are made up of employees; what employees say and do creates the corporate reputation.

Ethics is everything. Marilee Jones, dean of admission at MIT from 1997 to 2007, was asked to resign because she failed to correct false claims contained in her resume regarding three college degrees which she had not actually earned.

Corporations take steps to address ethics-related issues. According to Schwartz (2002), over 90% of large U.S. corporations have formulated company-specific codes of ethics. This trend is expanding to corporations in other countries as well. For example, in Canada, the United Kingdom, Germany, and France, the percentage of companies with codes of ethics is 85, 57, 51, and 30, respectively. A code of ethics is a formal, written document that contains normative guidelines for behavior. Publishing and implementing such a code allows a corporation to provide a set of consistent standards for employees to follow, both to avoid any adverse legal consequences due to possible wrongdoings and to promote a wholesome public image. Harry Emerson Fosdick said, “No virtue is more universally accepted as a test of good character than trustworthiness.”

11.2.1 Universal Moral Standards

Whether a code of ethics contains right or wrong guidelines depends on the benchmark standards used to make the assessment. Schwartz (2002) has assembled a set of universal moral standards that appear to be intuitively correct.

These standards include six elements: (1) trustworthiness (honesty, integrity, reliability, and loyalty), (2) respect (respect for human rights), (3), responsibility (accountability), (4) fairness (process impartiality and equity), (5) caring (avoiding unnecessary harm), and (6) citizenship (obeying laws and protecting the environment). By using such a set of universal moral standards as a yardstick, different codes of ethics can be compared and evaluated.

Ethics in the workplace may be discussed within three different scopes—ethics in engineering, management, and business—depending on the expected complexity of the situation and the potential impact on stakeholders.

11.2.2 Engineering Ethics

Science, technology, engineering and math (STEM) professionals, including engineers, play key roles in the advancement, production, and use of technology. They should therefore assume a degree of responsibility for the consequences of applied technologies. Fleddermann (2011) and Harris et al. (2013) address different aspects related to engineering ethics.

Engineering companies publish codes of ethics to guide engineers in performing their work in an ethically and socially responsible manner. A large number of engineering societies, such as the National Society of Professional Engineers (NSPE), the American Society of Civil Engineers (ASCE), the American Society of Mechanical Engineers (ASME), and the Institute of Electrical and Electronics Engineers (IEEE), have also issued codes of ethics to provide discipline-specific guidelines. In addition, the files of NSPE's Board of Ethical Review contain various types of issues in engineering ethics and their respective resolutions.

Pinkus et al. (1997) have noted that there are three principles of engineering ethics: competency, responsibility, and public stewardship. Competency means that engineers are obliged to know as much as is reasonably possible about the technology with which they work. They should be honest and candid enough to acknowledge their own deficiencies and seek assistance from others to fill in any gaps. Responsibility requires that engineers voice their concerns when an ethical dilemma is identified. Responsible organizations must then evaluate these concerns promptly. With respect to public stewardship, engineers must understand the risks associated with the technology that they deploy.

A key concept in engineering ethics is the notion of *professional responsibility*, a type of moral obligation arising from the special responsibility possessed by an individual engineer. According to Whitebeck (2011), this moral responsibility requires that engineers exercise judgment and care to achieve and maintain a desirable state of affairs, as well as to protect public health and safety.

A large number of U.S. engineering schools are now actively involved in teaching ethics in undergraduate curricula. The Accreditation Board of Engineering and Technology (ABET) reviews and accredits countless engineering school programs in the United States on a regular basis. ABET has defined a specific program outcome related to ethics in its *Engineering Criteria 2000*. This program prescribes that graduates are to have an understanding of professional and ethical responsibility and the broad education necessary to understand the impact of engineering solutions in a global and societal context. The ABET

Engineering Criteria 2000 have been implemented since the fall of 2001. Its contents include the following 11 outcomes:

1. Apply knowledge of mathematics, science, and engineering.
2. Design and conduct experiments, as well as analyze and interpret data.
3. Design a system, component, or process to meet desired needs.
4. Function on multidisciplinary teams.
5. Identify, formulate, and solve engineering problems.
6. Understand professional and ethical responsibility.
7. Communicate effectively.
8. Have the broad education necessary to understand the impact of engineering solutions in a global and societal context.
9. Recognize the need for, and have the ability to engage in, lifelong learning.
10. Have knowledge of contemporary issues.
11. Use the techniques, skills, and modern engineering tools necessary for engineering practice.

Teaching ethics to engineering students is aimed at achieving four outcomes: (1) raising ethical sensitivity, (2) increasing knowledge about relevant standards of conduct, (3) improving ethical judgment (e.g., by way of discussions of real-world cases), and (4) strengthening ethical willpower to enable a greater capability to act ethically. Teaching ethics illustrates real-world complex relationships between technology development and the welfare of individuals, society, and the environment. It also promotes an understanding of the professional nature of engineering and of the responsibilities associated with a professional career. It enhances the engineers' abilities to analyze situations that raise questions about ethics and to articulate reasonable ways to respond to ethical dilemmas.

In recent years, there have been a number of major engineering ethics cases reported in the engineering and business literature. Table 11.1 lists some sample cases. The case method of teaching ethics encourages students to express ethical opinions, prompts them to identify ethical issues, and helps them formulate and justify decisions in an effectual manner. The case method also seeks to strengthen students' sense of the practical context of ethics.

1. *The Hooker Chemical case*: Located in Niagara Falls, New York, Love Canal was 10 feet deep, 60 feet wide, and 3000 feet long and surrounded by a virtually impervious clay soil. Hooker Chemical obtained permission to use the canal for dumping waste chemicals in 1942 and subsequently acquired a strip of land 200 feet wide with the canal in the center. Hooker sealed chemical wastes into steel drums, dropped them into the canal, and covered them with a layer of clay. Approximately 22,000 tons were deposited from 1942 to 1953. At the time, there were no federal or state regulations governing the dumping of chemical wastes (Beck 1979).

   In 1953, Hooker closed the dump and sold the land to the city's board of education for $1 after the board threatened to condemn the land. Hooker included a clause in the deed to the board describing the past use of the land and required

TABLE 11.1

Sample List of Engineering Ethics Cases

No.	Case	References
A	Hooker Chemical—Love Canal, 1978	Gary Whitney. Case Study: Hooker Chemical and Plastics, in T. Donaldson (editor), *Case Studies in Business Ethics*. Englewood Cliffs, NJ: Prentice-Hall, 2001.
B	The collapse of walkways at Hyatt Regency Hotel in Kansas City, 1981	http://ethics.tamu.edu/ethics/hyatt/hyatt1.htm. E. Pfrang and R. Marshall. Collapse of the Kansas City Hyatt Regency Walkways. *Civil Engineering-ASCE*, July 1982.
C	DC-10 cargo-door accident case near Paris, 1974	P. French. What Is Hamlet to McDonnell-Douglas or McDonnell-Douglas to Hamlet: DC-10. *Business and Professional Ethics Journal*, 1(2), 1982.
		J. Fielder and D. Birsch. *The DC-10 Case: A Study in Applied Ethics, Technology and Society*, Albany, NY: State University of New York Press, 1992.
D	Spiro Agnew and construction kickback in Maryland, 1973	Richard M. Cohen and Jules Witcover. *A Heartbeat Away: The Investigation and Resignation of Vice President Spiro Agnew*, New York: Viking, 1974.
E	Space shuttle *Challenger* explosion, 1986	R. L. B. Pinkus, L. Shuman, N. P. Hummon, and H. Wolfe, *Engineering Ethics: Balancing Cost, Schedule and Risk, Lessons Learned from the Space Shuttle*, New York: Cambridge University Press, 1997.

that the board assume the risk of liability for any future claims that might result from the buried chemicals.

Subsequently, the board constructed a school on part of the land and sold the remainder to a developer, who built homes for families. None of the homes were built directly over the canal. In 1978, traces of chemicals were noted on the surface of the land. Residents complained of increased rates of miscarriage, birth defects, urinary tract infections, and other health-related problems. In August 1978, President Carter declared Love Canal a limited disaster area. Federal investigators took 5000 soil samples but failed to establish a direct link with the buried chemicals.

2. *The Hyatt Regency Walkways case*: During a dance party in July 1981, two walkways suspended over the atrium of the hotel lobby collapsed, killing 114 people and injuring 185 others. Detailed investigations indicated that the mechanical supports for the walkways were insufficiently designed for the anticipated loads. The license of the engineering firm responsible for the design was revoked (Pfrang and Marshall 1982).
3. *The space shuttle Challenger case*: In the well-known space shuttle *Challenger* explosion case, the night before the launch, Morton Thiokol engineers had identified the potential danger of launching the shuttle in temperatures less than 53°F. NASA management challenged the recommendation. During an off-line discussion among Morton Thiokol participants in Utah, a vice president of engineering was the only one among four to hold out for a launch delay. A senior vice president told him bluntly, “It’s time to take off your engineering hat and put on your management hat.” The vice president capitulated, and the launch went forward, resulting in the disaster on record. This episode and the

anecdote about engineering and management "hats" are now widespread in the literature on engineering ethics (Rossow 2012).

11.2.3 Management Ethics

Should there be any difference between engineering ethics and management ethics? Not a lot, except that managers must consider broader issues and deal with ethical situations more complicated than those typically encountered by individual engineers and STEM professionals. Leigh (2013) and Schminke (2010) include some discussion on management ethics.

In the space shuttle *Challenger* case, the Morton Thiokol management standpoint was as follows. The company was a contractor to NASA and had clearly expressed its technical concerns related to the launch. Even though the recommendation was not fully supported by available data, the company did fully discharge its moral and ethical responsibility in the O-ring issue. The proper role for Morton Thiokol was, indeed, to respect the view of its client. If NASA, as the paying client, decided to launch the shuttle anyway, then the responsibility for any negative consequences rested entirely with NASA.

From the NASA management standpoint, the O-ring issue was technically not supportable by data. On the other hand, NASA had its mission goals to fulfill. Under such circumstances, someone made a decision under uncertainty based on gut feeling and personal experience in risk assessment. Unfortunately, the decision turned out to be wrong. However, management is paid to make such hard decisions under uncertainty.

Generally speaking, engineering managers consider factors related to the well-being of the organization, such as cost, schedule, employee morale, customers, supply chains, investors, public image, local communities, health and safety, social and environmental impacts, market development, profitability, and globalization. Engineers and STEM professionals, on the other hand, focus on technical matters that fall within their professional engineering practices, such as product design, production, technology, public health and safety, and environmental impact.

Example 11.1

The ocean liner SS *United States* was a luxurious ship in the 1950s. It had approximately one-half-million square feet of harmful asbestos insulation. Initial estimates indicated that it would cost $100 million to have it refurbished in the United States. In 1992, it was towed to Turkey, where the cost of removing the asbestos was quoted at only $2 million. Turkish officials, however, refused to allow the removal because of the danger of exposure to the cancer-causing asbestos. In October 1993, the ship was towed to the Black Sea port of Sebastopol, where laws were lax and the removal of asbestos would cost less than $2 million.

Do you approve of the program that removed asbestos from the SS *United States* at Sebastopol? Why, or why not?

Answer 11.1

The ethically correct answer is to disapprove. The removal of asbestos at Sebastopol was economically attractive for the shipowner, because the local laws did not require specific safeguards and safe processes needed for effectively protecting the health of workers. Thus, the cost saving was derived by taking advantage of the ignorance of the local people and the inadequacy of the local laws. The program had the potential for damaging the health of workers at Sebastopol, a blatant violation of core human rights. It should have been rejected without reservation.

11.2.4 Ethics in Business

As engineering managers move up the corporate ladder, they become more and more involved in influential decision-making that extends beyond the traditional domains of engineering and technology. Guidelines related to ethics in business kick in at that time to help shape the decision-making.

Such situations arise from the fact that business management must take care of the broad interests of five stakeholder groups: shareholders, customers, employees, suppliers, and people in local communities in which the company operates. Business managers must also remain consistent in their professional responsibilities and ethical standards. Note that all of these stakeholders are members of society at large, but they represent only a small part of it (see Figure 11.1). Thus, inherently, there will be situations in which choices made to pursue the interests of these five stakeholder groups may clash with the interests of the remaining members of society. Although an ethical company must attempt to eliminate or minimize such clashes, conflicts of this type are likely to occur.

In fact, actual situations in real environments are far worse than this. As indicated in Table 11.1, questions have been raised concerning the conflicts of interest reflected in the management of numerous U.S. corporations. The U.S. public perceive that many companies unethically put the top managers' own interests ahead of those of the five major stakeholder groups. Congress passed the Sarbanes–Oxley Act of 2002, the Public Company Accounting Reform and Investor Protection Act, to more tightly regulate some of the questionable accounting practices.

Ferrell and Fraedrich (2014) studied 20 business ethics cases, including Bernard Madoff (a Ponzi scheme to defraud investors), Enron (corporate financing reporting), and Gallon (insider trading to realize illegal gains). Tichy and McGill (2008) offer additional discussions on Arthur Anderson, Tyco International, WorldCom, and Quest.

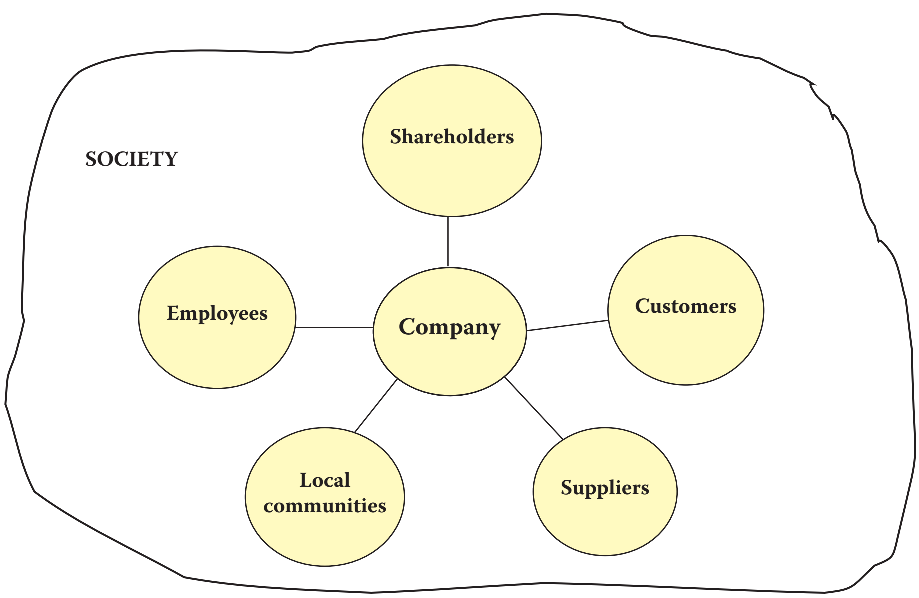

FIGURE 11.1
Stakeholders of a company.

In September 2015, Volkswagen (VW) admitted that the company had used special software to reduce the nitrogen oxide emission of its 11 million diesel trucks so that they would fraudulently pass the Environmental Protection Agency (EPA) emission standards. VW stock dropped by 19% following this admission. The company took a charge of $7.2 billion and faces a raft of 34 federal lawsuits. It also expects to be further penalized by up to $18 billion by the government. Early in the year, General Motors (GM) was cited for its faulty ignition switches, which had been covered up over many years and had caused the death of 124 people and injured hundreds of others. GM was eventually fined $900 million for this dishonest practice. Toyota paid $1.2 billion to settle criminal charges related to unintended accelerations of its cars.

McDonald (2014), Shaw (2010), and Hoffman et al. (2014) offer additional viewpoints related to business ethics.

11.3 Guidelines for Making Tough Ethical Decisions

Everyone could use guidelines when making tough ethical decisions. Peter Drucker, a well-known business management professor, recommends a *mirror test*. Ask yourself, "What kind of person do I want to see when I shave or put on my lipstick in the morning?" (Seglin 2000). This method may not deter those violators who are self-serving and who apply double standards to justify what they do.

Norman Augustine, former CEO of Lockheed Martin, has proposed four questions to gauge how ethical a course of action is:

1. Is it legal?
2. If someone else did it to you, would you think it was fair?
3. Would you be content if it appeared on the front page of your hometown newspaper?
4. Would you like your mother to see you do it?

If you answer "yes" to all four questions, then, according to Augustine, whatever you are about to do is probably ethical. Following this method of screening, one is then advised to always have the cell phone numbers of a lawyer, the editor of the hometown newspaper, and one's own mother on hand, plus a well-calibrated, unbiased "barometer" of fairness.

Badaracco (2013) believes that character is forged in situations when responsibilities come into conflict with values. These situations are called *defining moments*. At defining moments, managers must choose between right and right. Badaracco suggests a set of questions for individuals, managers of working groups, and executives of companies to answer when evaluating such defining moments:

1. *Questions for Individuals Facing Defining Moments*

   What feelings and intuitions come into conflict in this situation?

   Which of the values in conflict are most deeply rooted in my life?

   What combination of expediency and shrewdness coupled with imagination and boldness will help me implement my personal understanding of what is right?

2. *Questions between Right and Wrong that Managers of Working Groups Must Answer*

   What are the other persuasive interpretations of the ethics of this situation?

   What point of view is the most likely to win a contest of interpretations inside of my organization and influence the thinking of other people?

   Have I orchestrated a process that can manifest the values I care about in my organization?

3. *Questions that Confront Company Executives*

   Have I done all that I can to secure my position and the strength of my organization?

   Have I thought creatively and boldly about my organization's role in society and its relationship with stockholders?

   What combination of shrewdness, creativity, and tenacity will help me transform my vision into reality?

Some managers are constantly required to resolve the conflict between discharging their responsibility to maximize shareholder value, on the one hand, and behaving in an ethical manner, on the other. Bagley (2003) suggests a simple decision tree to guide managers in making ethical decisions in any corporate projects (see Figure 11.2).

Bagley advises managers to raise three questions: (1) Is it legal? (2) Does it maximize shareholder value? and (3) Is it ethical? Managers should refuse to pursue any project or take any action if the answer to any of these questions is "no." However, managers should decide to carry out projects that are legal and ethical, even if these projects do not maximize shareholder value, as long as pursuing them could benefit the other stakeholders of the company (see Figure 11.1). The argument is that managers work for the best interests of the company, and these best interests may not always require them to maximize shareholder value.

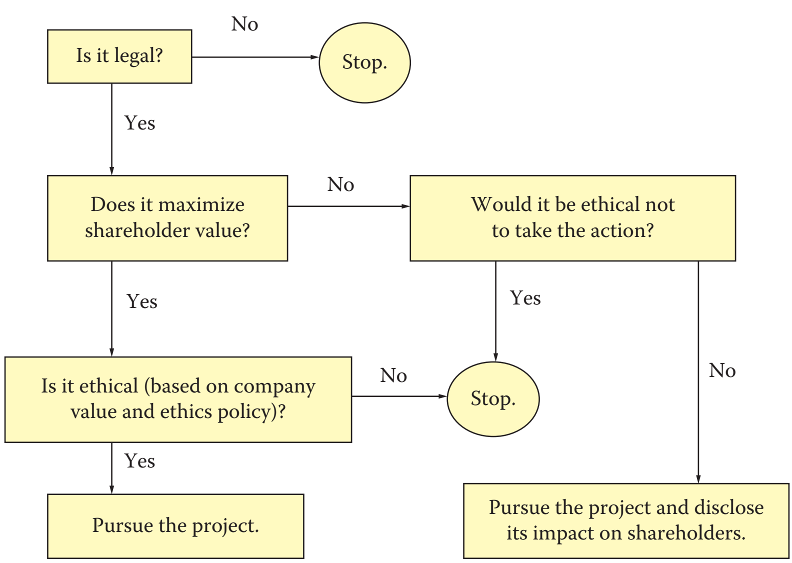

FIGURE 11.2
Decision tree to guide decision-making related to ethics.

The logic of this decision tree model is rather compelling. But a major weakness of this model is that, for some courses of action, the answers to the questions related to shareholder values and ethics will likely be "maybe" instead of a clear-cut "yes" or "no."

In the *Challenger* case, Morton Thiokol engineers and managers argued for a delay of the launch due to a suspected O-ring failure under low-temperature conditions. In contrast, NASA managers were under pressure to proceed with the launch as scheduled. Numerous questions were raised. Did Morton Thiokol have to prove that the flight was unsafe for the launch to be delayed? There were no data that could conclusively substantiate the recommendation of a launch delay. Should NASA managers have allowed factors other than engineering judgment to influence the flight-schedule decision? From the following two options, which stand should NASA have taken? (1) Do not fly if it cannot be shown to be safe; (2) fly, unless it can be shown to be unsafe. Certainly, the NASA program objective to build the shuttle for about half of the originally proposed cost might also have contributed to the decisions that resulted in disaster.

According to the decision tree model presented in Figure 11.2, it is clear that NASA had the legal authority to decide. When it comes to the second question, shareholder value, the answer was not clear-cut. Two options were under consideration at the time:

1. Launch the shuttle as scheduled. The benefits of a successful launch were expected to be the continued enhancement of the value of NASA programs to the American people and to the scientific communities, and the preservation of public trust and confidence in the capabilities of NASA management. On the other hand, if the launch were unsuccessful, then there would be a significant sacrifice of human life, the destruction of physical assets, and the loss of the public's goodwill. Perhaps some personnel changes at NASA would have become necessary under that scenario.

   The key problem was that neither Morton Thiokol nor NASA had data to confirm that the launch would definitely be unsafe. It was only the best judgment of Morton Thiokol engineers that the launch might be unsafe. The expected cost of a launch failure could not be quantitatively estimated, because there was no reliable number for the probability of the O-ring to fail at low temperatures.
2. Delay the launch till temperatures were right. The cost of such a delay would have been the loss of public confidence in NASA managerial competency and certain operational and equipment maintenance costs associated with a delay.

Depending on the assumed value of the probability of occurrence for the O-ring failure, the expected cost for Option 1 could change. Thus, the question related to shareholder value in Figure 11.2 should be answered "maybe." To move forward from this point on would require the introduction of an assumption (usually unproved and likely relying on gut feeling or an extrapolation from past experience) related to the probability for the O-rings to fail. Determining an accurate probability becomes a judgment call. Apparently, NASA management believed that the probability for the O-rings to fail was extremely low.

NASA's assumption of an extremely low probability for the O-rings to fail also led to a "yes" answer to the third question related to ethics in Figure 11.2. If this probability of O-ring failure had been high, then it would have been unethical for NASA to decide on a course of action that would have been likely to lead to the demise of the shuttle crew. An academic ethicist (Werhane 1991) evaluated the *Challenger* disaster and concluded that it was the result of four kinds of difficulties: (1) different perceptions and priorities of engineers and management at Thiokol and at NASA; (2) a preoccupation with roles and responsibilities on the part of engineers and managers; (3) contrasting corporate cultures at Thiokol and its parent, Morton; and (4) a failure by both engineers and managers to exercise individual moral responsibility. (For a detailed discussion of the space shuttle *Challenger* case, see Vaughan 1996.) While the decision tree model is generally useful, its application can become complicated when conflicts of interest arise among the stakeholders. What happens if value is added to one group of stakeholders at the expense of others? The following examples illustrate this type of situation.

1. Some U.S. company boards routinely approve bonus and stock options to top managers to offer them extra incentives at the expense of shareholders. This practice contributes to the distorted corporate emphasis indicated in Table 11.1. Such practices are not common in other industrialized countries.
2. When involved in mergers and acquisitions, some top managers negotiate for special separation contracts to benefit themselves at the expense of the surviving company.
3. Companies outsource manufacturing operations to developing countries where environmental and safety regulations are typically less stringent than in the United States; this achieves cost advantages for the companies at the expense of the communities in which they operate and of the employees in the developing countries.
4. Companies sell unsafe automobiles and drug products to consumers, causing deaths due to accidents or side effects, while realizing sales revenue and profitability for themselves.
5. The U.S. Securities and Exchange Commission (SEC) announced its settlement with 10 Wall Street security firms to restore public trust. These firms agreed, without admitting any wrongdoing, to pay a fine of $1.4 billion for giving biased stock investment advice that had caused investors to lose money during the recent past and delivered huge financial benefits to the firms involved.

The troubling point here is that all the decision-makers involved in these cases were fully aware of the ethical implications related to their actions. Thus, knowing what is ethical and what is unethical is clearly only the first step. The decision tree in Figure 11.2 offers a logical road map to force a needed critical review of all management decisions. However, additional steps beyond making knowledge available are required to ensure that all decisions carried out are ethical at all times and under all circumstances.

11.4 Corporate Ethics Programs

Building an efficacious corporate ethics program requires leadership, commitment, planning, and execution. According to Navran (1997), companies need to have clear statements of their vision and values. They should have an organizational code of ethics. Creating an ethics officer position and forming an ethics committee helps communicate the company's ethics strategy, coordinate employee training, maintain a help line to offer confidential advice as needed under specific circumstances, monitor and track activities with ethics implications, and take action to reward good and punish unethical practices.

More than 90% of all Fortune 500 companies have codes of ethics, and 70% have statements of vision. Companies such as Procter & Gamble, IBM, Johnson & Johnson, Texas Instruments, John Deere, Cummins Engine, Eaton, and Dow Corning publish codes of ethics online. The Center for the Study of Ethics in the Professions at the Illinois Institute of Technology received a grant from the National Science Foundation to design and maintain a website, www.ethics.iit.edu/ecodes/about. The site stores 850 codes of ethics online, including those issued by engineering associations (Section 11.2.1) and corporations.

A corporation's statement of ethics serves as a behavioral compass for the employees. Kinni (2003) recommends a set of guidelines to formulate a code of ethics. Companies must first establish their values and direction. To be relevant, a statement of ethics must be connected to the core direction in which the organization is going. The code of ethics should be centered on such values as integrity and trustworthiness, instead of being merely a compliance document. It should include specifics unique to the business under consideration or details about the company philosophy. The company should then go public with the code of ethics so that all employees, customers, suppliers, and any other stakeholders are fully informed of it. The code of ethics must be updated regularly to help guide the day-to-day behavior and decision-making of the employees. The overall effectiveness of a statement of ethics depends on the company leaders' commitment to its disciplined enforcement. (Examples of ethics statements can be found in Murphy, 1997.)

It is useful to issue guidelines to handle potentially unethical situations and to set clear standards of conduct applicable to daily responsibilities. Employees are advised to (1) analyze carefully the situation at hand; (2) list all possible failings and downsides of the potentially unethical practice in question; (3) compile all possible benefits that could accrue if the practice in question ceases and is admitted now, rather than being discovered by someone else later; (4) issue a memo; and (5) attempt to make a full disclosure to coworkers, the superior, the superior's superior, the company president, the customers, the public, and the press.

Besides defining what the employees are expected to do, it is equally important to spell out what they should not do. Of specific value is the description of actions that are deemed unethical. Setting such lower bounds ensures that there is no ambiguity in interpreting what is not allowed. As sample unethical cases from both internal and external sources are continuously added to the code of ethics, the resulting casebook will become an increasingly important benchmark reference.

Honeywell has put teeth into its ethical principles by making it mandatory for all employees to adhere to the company's code of conduct. Starbucks introduced its Framework for a Code of Conduct for coffee-producing countries to standardize ethics practices among coffee retailers, exporters, and growers.

Some people believe that it is ineffective for companies to self-police their own codes. Instead, there should be an independent monitoring of ethical practices. To deter wrongdoing, the penalties must be high and the enforcement disciplined. Among examples of such penalties are dismissal with charges and forfeiture of all pension rights, a jail term with no opportunities for parole, severe financial penalties, and denial of reentry to industries involved.

There should probably also be more recognition from society for good actions taken by companies or individuals. Making ethically sound decisions may have been taken for granted by many people for a long time. In 1998, *Deloitte/Management Magazine* created a

Business Ethics Award program in New Zealand, and it has recognized the following companies with best practices in ethics since that time: Norske Skog Tasman in 2002, Methanex NZ in 2001, *New Zealand Post* in 2000, and 3M New Zealand in 1999. More awards of this type should be established to honor such people and to reflect society's appreciation of these exemplary ethical behaviors!

In managing corporate ethics programs, the key is to make sure that everyone is honest and will disclose fully all of the details of every situation in question. A well-known publisher suggests a single question as the basis for assessing an ethical situation: "If what I just said or neglected to say, did or neglected to do, saw and failed to report, or heard and failed to mention, were disclosed openly by someone else in reputable communications channels, would it embarrass me, my organization, or my family?" If the answer is "yes," then the action or inaction in question is unethical. This question is likely to be useful for honest people with self-respect. However, embarrassment is a personal perception based on value. It may not be as useful to white-collar crooks who are driven by greed and who are willing and able to circumvent the laws to act unethically. Generally speaking, individuals who offer a full disclosure to all concerned are usually ethical (Johnson and Phillips 2003).

The commitment of top management to the corporate ethics program is of critical importance to its success. A case in point is Johnson & Johnson. The company is known for its Credo Challenges sessions, in which employees and managers talk about ethics related to current business problems and offer criticisms of existing policies and ideas for improvement. The company achieved excellent business results by using this industrial best practice in the field of ethics.

An opposite case in point is Enron, which had a 65-page code of ethics. Yet, some top Enron managers allegedly entered into special business deals with off-balance-sheet financing that resulted in a falsely inflated corporate profitability that permitted selected management personnel to cash out stock options while siphoning out special bonus payments to individuals, all eventually at the expense of the company shareholders. Reports from internal whistleblowers were simply ignored by Enron top managers, who elected to take no corrective action. It was clear to everyone involved that these were unethical and illegal management actions. Allegedly acting as its partner in crime, the auditing firm Arthur Andersen was also accused of committing the criminal offense of willfully destroying Enron papers relevant to the case.

No ethics program will be efficacious unless company top management supports its implementation.

Example 11.2

A global job migration trend is starting to develop. Significant numbers of jobs are being exported from the United States and other developed countries to such emerging-economy countries as Mexico, China, India, the Philippines, Ireland, Thailand, and Bangladesh. Typical jobs are related to software programming, call center services, financial accounting, tax preparation, selected R&D, claims processing, and contract production. Other types of jobs may be involved in the future. The principal driving force behind the job migration trend is cost: a comparable quality of workmanship may be accomplished in emerging economy countries at about one-third the cost of paying workers in developed countries.

Does Corporate America display an apparent indifference to its workforce at home? Is it unethical for American companies to outsource work in search of cost-effectiveness at the expense of American workers?

Answer 11.2

Corporate America is legally empowered to seek cost-effectiveness in creating and marketing products and services, as long as it is doing so in compliance with laws and commonly accepted ethics standards. Because of the free market system the United States practices, Corporate America does not have the obligation to guarantee jobs for any sector of American workers, be they engineers, software programmers, accountants, claims-processing clerks, call center service personnel, or factory workers. If certain sectors of employment appear to be declining because of global competition, the workers in these affected sectors must be able to learn new skills quickly to keep themselves competitive in the job market. Past cases with textile, steel, and agriculture workers are typical examples of sector-specific decline due to globalization.

The job protection concept may be appropriate in a socialist system, wherein the government exercises control over the economy, but it is not appropriate in a free market economy. By outsourcing, Corporate America does not display an apparent indifference to its workforce at home. It is not unethical for American companies to outsource work.

11.5 Affirmative Action and Workforce Diversity

Related to corporate ethics is the issue of affirmative action. The law is very clear on this issue. In 1964, the Civil Rights Act was enacted to ban discrimination on the basis of a person's color, race, national origin, religion, or sex. The Equal Employment Opportunity Act was passed in 1972, empowering the Equal Employment Opportunity Commission (EEOC) to enforce Title VII of the Civil Rights Act. The EEOC directives do not allow discrimination in hiring, placement, training, advancement, compensation, or other activities against any person on the basis of race, color, religion, national origin, gender, age, disability, marital status, or any other such characteristic protected by law. These acts have been enforced, and progress in affirmative action has been made over the last several decades (Byrd and Scott 2014; Ferdman and Deane 2013).

For the past 30 years or more, a number of private colleges and universities have introduced race-sensitive admissions policies to increase the number of African-American, Hispanic, and Native American students they enroll. Bowen et al. (1999) defend such policies on the grounds that these institutions have the right to define the preferred composition of their student bodies. In recent years, there have been more state or institutional actions taken against such policies. In 1996, California abolished affirmative action programs and decided to stop using race and gender as college admission factors. Washington State followed the Californian example in 1998. In 2000, Florida joined this anti-affirmative action movement.

Massachusetts Institute of Technology, Cambridge, Massachusetts, excluded white students from its annual summer mathematics and science programs for incoming freshmen and high school students. In 2002, a complaint was filed with the Department of Education's Office of Civil Rights. Subsequently, MIT opened the programs to all students.

The University of Michigan has a well-known undergraduate admissions policy that allows 12 points for a perfect SAT score and adds 20 points if the applicant happens to be black, Hispanic, or Native American, but assigns no points for being white or Asian. Figure 11.3 illustrates the changing race and ethnicity composition of undergraduate students admitted to the University of Michigan. The United States Supreme Court announced its famous "split decision" in 2003: the vote was against the points system, but in favor of a race-based admissions policy for the University of Michigan Law School to use in the

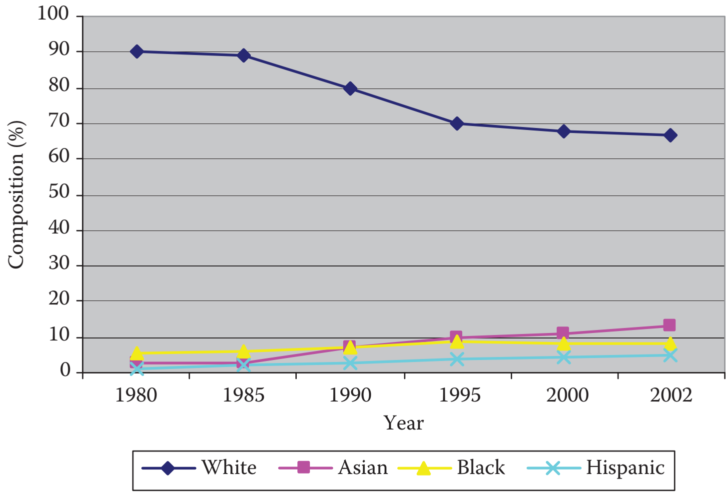

FIGURE 11.3
University of Michigan composition of admitted students.

absence of a points system. Proponents on both sides of this issue were able to claim victory. Is it fair to those white students whose admissions were denied just because of their race and ethnicity? Questions such as this remain unresolved.

Even after companies allow more minorities and women to gain entry, there is still an atmosphere of tension, instability, and distrust between white and nonwhite managers, according to Carver and Livers (2002). Minority managers have a high turnover rate, and they encounter deep-rooted, complex, and highly personal attitudes and assumptions in their coworkers.

Thomas (1990) argues that companies need to move beyond affirmative action and to strive for equal opportunities for everyone in the workforce as a way of creating competitive advantage in a global economy. Globalization may, indeed, precipitate workforce diversification and force everyone to work with everyone else, regardless of values, culture, race, or gender. Thomas and Ely (1996) indicate that companies should use the integration paradigm to promote equal opportunities for all people, promote open discussion of diverse cultural issues, eliminate all forms of domination (by hierarchies, race, gender, etc.) that inhibit full contribution, and secure organizational trust.

For sure, this debate will rage on. In the meantime, engineering managers are well advised to constantly treat everyone and every situation honestly and fairly and to value each person's contributions properly.

11.6 Global Issues of Ethics

The problems of ethics are broader in complexity and scope for companies with a global reach than for companies that operate domestically. This is because the values, business practices, laws, environmental and safety standards, and other related references for making ethical decisions differ depending on the countries involved (Moliterno and Platon 2014; Widdows 2014).

Engineering managers encounter problems with global ethics implications in a number of ways. Some problems related to product safety, plant operations, environmental discharges, work rules, and child labor are to be expected. Managers may need to interact with local governments with respect to permits, customs, transportation services, and procurement of parts and materials. They may also need to set up local supply chains and require all local participants to comply with specific codes of conduct.

Take environmental standards as an example. Countries that are economically active consume a disproportionate amount of energy and natural resources per capita compared with emerging economy countries. According to the World Bank's *Little Green Data Book* for 2003, America uses 16 times as much energy per person than India. About 15% of the world's population living in rich countries are responsible for 50% of the overall emissions of carbon dioxide, the principal gas behind global warming. The question may be asked whether it is ethical and socially responsible for the economically active countries to pollute more than others.

Another example is related to values and business practices. Figure 11.4 displays the study results of Transparency International, a Berlin-based organization. According to this worldwide study, the least ethically corrupted country is Finland, followed by Singapore, and then Great Britain, Hong Kong, Germany, and the United States.

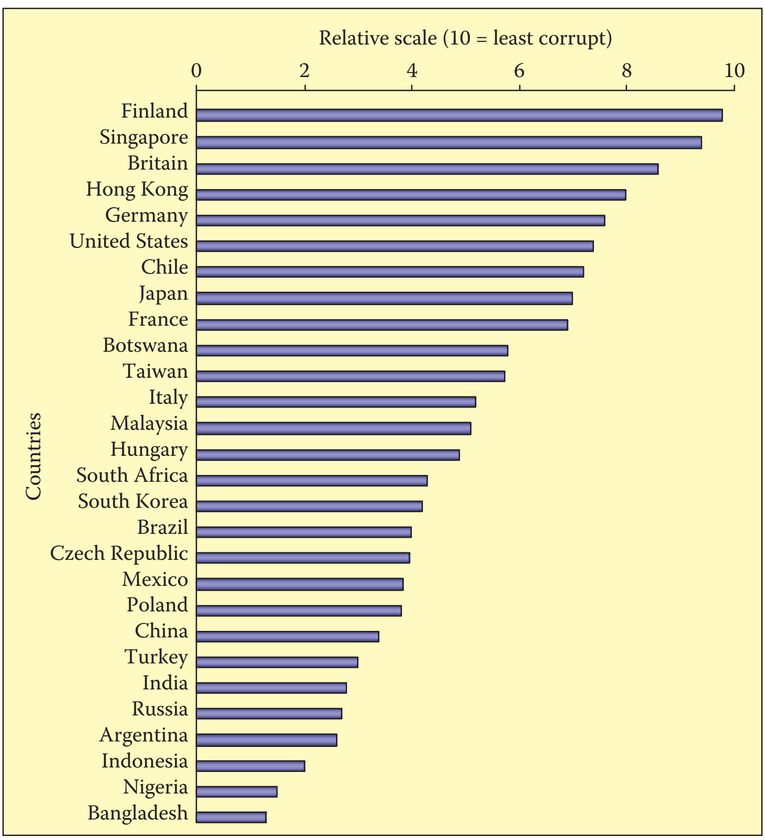

FIGURE 11.4
List of most honored countries.

Yet another problem that has global ethics implications has to do with the law. In 1977, the U.S. Congress enacted the Foreign Corrupt Practices Act, which requires American parent companies and their foreign subsidiaries to abide by certain business standards (Koehler 2014). This act has three provisions:

1. *Recordkeeping and disclosure provision*: This provision requires that companies shall "make and keep books, records and accounts, which, in reasonable details, accurately and fairly reflect the transactions and disposition of the assets of the issuers." Not recording and disclosing payments (such as bribes) ma…de to foreign recipients is an offense clearly prosecutable under this provision.
2. *Internal controls provision*: This provision prescribes that companies have audit committees composed of independent, outside members of their boards of directors to provide independent financial audits. Not exercising proper managerial control in the use of funds (such as accepting bribes or other illegal payments) is a violation of this provision.
3. *Antibribery provision*: This provision prohibits payments to foreign officials, foreign political candidates, or foreign political parties intended to corrupt those recipients who act in favor of the companies. Doing so is against the Act even if it does not violate the laws of the respective countries involved. However, "grease payments" in the form of entertainment expenses and small gift items to minor officials are generally allowed for the purpose of facilitating transactions. The Act is silent with respect to the actual dollar amount above which this provision is deemed to be violated, leaving such interpretations to the courts.

The Act regards the integrity of management as a material factor. Engineers and engineering managers need to become familiar with and sensitized to these provisions when engaged in interactions with foreign personnel. When in foreign countries, the applicable local laws must be obeyed as well. Thus, it should be self-evident that any course of action that violates any laws, either of the home country or of the host country, must not be undertaken.

The issue related to the bribery of foreign public officials is a troublesome one. Some researchers, such as Tarun (2014), have questioned the positive impact of the Foreign Corrupt Practices Act on overall standards of international business conduct, particularly with respect to the bribery of foreign public officials.

Problems involving environmental discharge or child labor may cause engineering managers to be fearful of another law. The Alien Tort Claims Act has been used to prosecute U.S. companies for alleged human rights violations and environmental degradation abroad. Olsen (2002) reports three such industrial cases.

Even if all of the actions taken by engineering managers are lawful, it is possible that not all lawful business decisions they make are ethical. It is usually quite complex to determine whether a given course of action taken in a host country is ethical or not, because the contrasts between the cultures, values, and customs of the host and home countries come into play. A number of examples cited by Donaldson (1996) illustrate these differences:

1. Indonesians tolerate the bribery of public officers. Bribery is considered unethical and unlawful in the United States.
2. Belgians do not find insider trading morally repugnant. Insider trading is a criminal offense in the United States. For example, Martha Stewart was indicted

and subsequently convicted for having committed conspiracy, making false statements, and obstruction related to her suspicious sales of InClone Systems stocks. She resigned as CEO of her company and was sentenced to serve time in prison.

3. In some countries, loyalty to a community, a family, an organization, or a society is the foundation of all ethical behavior. The Japanese people define business ethics in terms of loyalty to their companies, their business networks, and their nation. The Japanese are group oriented. In contrast, Americans place a higher value on liberty than loyalty and emphasize equality, fairness, and individual freedom over group achievements. Americans are focused on individualism.
4. The notion of a right or entitlement evolved with the rise of democracy in post-Renaissance Europe and the United States. This term does not exist in either Confucian or Buddhist traditions.
5. Low wages may be considered by workers in wealthy countries (e.g., the United States and Europe) as an exploitation of the workforce, but developing nations may be acting ethically when they accept low wages to induce foreign investment to improve their living standards.
6. Some emerging economy governments may want to use more fertilizer to enhance crop yields to combat food supply shortage problems, even though doing so would mean accepting a relatively high level of thermal water pollution.
7. A manager at a large U.S. specialty products company in China caught an employee stealing. She followed the company's practice and turned the employee over to the provincial authorities. The provincial authorities executed him.
8. In Japan, people who do business together exchange gifts, sometimes very expensive ones, as part of a long-standing tradition. Any foreign countries wanting to do business there will need to accept such practices as given.
9. Managers in Hong Kong have a higher tolerance for some forms of bribery than their Western counterparts, but they have a much lower tolerance for the failure to acknowledge the work of a subordinate. In some parts of the Far East, stealing credit from a subordinate for work or ideas is the most unethical activity.

   In the case of *The New York Times*, a staff writer stole credit by plagiarizing the writings of freelance writers and other sources. He did so for an extended period. Despite multiple warnings, the responsible editors did nothing to stop this staff writer from publishing. Finally, the staff writer resigned, and both editors were forced out.
10. Some Indian companies offer employees the opportunity for one of their children to get a job with the company once the child has completed a certain grade level in school. The company honors this commitment even when other applicants are more qualified. This perk would be regarded as nepotism in the United States, as it is against the principle of equal opportunity that jobs should go to the best-qualified applicants. On the other hand, some U.S. universities reserve certain admission quotas for children of alumni, major donors, and members of specific minorities.
11. The Swiss are known for their time sensitivity, whereas South Americans are known for their time laxity.

12. Forty percent of managers in the United States believe that the primary goal of a company is to make a profit, while only 33% in England, 35% in Australia, 11% in Singapore, and 8% in Japan share this belief.

There is a significant divergence in the perceived goals of a company from the manager's perspective. Once a company achieves its financial objectives, how should the money be distributed? Table 11.1 illustrates the emphasis of U.S. managers versus those of the general public in the United States. The self-centered approach of some U.S. managers could cause tensions and conflicts in values when dealing with foreign managers.

There is no international consensus on standards of business conduct (Williams 2000). Donaldson (1996) offers three basic principles as guidelines: (a) observing core human values, (b) showing respect for local traditions, and (c) focusing on the context when deciding what is right and wrong. Core human values determine the absolute moral threshold for all business activities. These values include the right to good health, economic advancement, and an improved standard of living. One must respect human dignity and recognize a person's value as a human being, and not treat others simply as tools. A good yardstick to use is the Golden Rule, which says: "Do not do to others what they do not want done to themselves."

This principle requires that customers be treated well through the generation of safe products/services, and employees through the maintenance of a safe workplace. Also, the local environment should be protected. Companies must avoid employing children and thereby preventing them from receiving a basic education. Local economic and education systems ought to be supported. Companies should forgo those business relationships that violate rights to health, education, and safety and prevent the development of an adequate standard of living.

Donaldson (1996) classifies ethics conflicts into two types: conflicts due to relative economic development and conflicts due to cultural tradition. Ethical situations of the first type are related to wages, safety, and the environment; they arise from a low level of economic development in the host country in comparison with the developed home country. To determine whether a given course of action is ethical, Donaldson suggests that the following question be raised: "Would the course of action under consideration be acceptable in my home country if our economic development were at the same stage as that of the host country?" If the answer is "yes," then the course of action is ethically acceptable. For example, if a specific emerging economy country is currently at the stage comparable to the United States in the 1970s, then U.S. rules and regulations related to wages, safety, and the environment in practice during the 1970s, not those in the 2010s, should be used to assess any situation involving ethical conflicts in that emerging economy country at the present time.

From time to time, courses of action must be taken even if they bring about conflicts due to cultural tradition if companies want to do business in a given host country. Generally, cultural tradition is to be respected and accepted. Saudi Arabia is known not to allow women to serve as corporate managers; most women there work in education and health care. Most foreigners who do business in Japan have now generally accepted the Japanese gift-giving tradition. Of course, compromises made in tradition-based conflicts must not violate core human values.

Some companies use a specific gift-giving strategy to be lawful, ethical, and compatible with local cultural tradition while promoting goodwill and fostering close working relationships. They elect to present two sets of gifts: a big and very expensive company-to-company gift and several small personal gifts, each being, for example, under $25.

Past practices have shown that such an approach seems to work out well for the parties involved.

Again, when handling global problems of ethics, the following are the basic questions: "Is it legal with respect to laws in both the host and home countries?" "Does the planned course of action violate basic human values?" "Is it consistent with the local cultural norms?" "Is there a creative way to reconcile the ethics issues at hand?" Figure 11.5 presents the decision tree diagram for global problems of ethics.

In handling challenging situations involving ethics in global settings, all managers and STEM professionals need to uphold core human values, account for the relevant local traditions, and be creative in problem solving to come up with a suitable and ethically acceptable course of action without violating laws (Tichy and McGill 2008).

Example 11.3

In the past, Levi Strauss engaged numerous contract manufacturers in emerging economy countries to produce athletic shoes. The company discovered in 1992 that two sewing subcontractors in Bangladesh employed children under the age of 14 in violation of company rules. The local economic conditions were such that the children were contributing significantly to their family income. If these under-aged children were discharged instantly, the lack of these income streams would cause economic hardship to the families involved. On the other hand, allowing the children to continue working clearly violated the stated company ethics policy prohibiting the employment of child labor.

What should Levi Strauss have done?

Answer 11.3

In fact, Levi Strauss came up with a creative solution to this ethics dilemma. The children were sent back to school with tuition, books, and uniforms fully paid for by the company. In addition, they continued to receive their full wages. They were promised jobs after they completed their education at the age of 14. This creative solution satisfied both Levi Strauss and the children's families.

This is a practical example of the creative steps indicated in Figure 11.5.

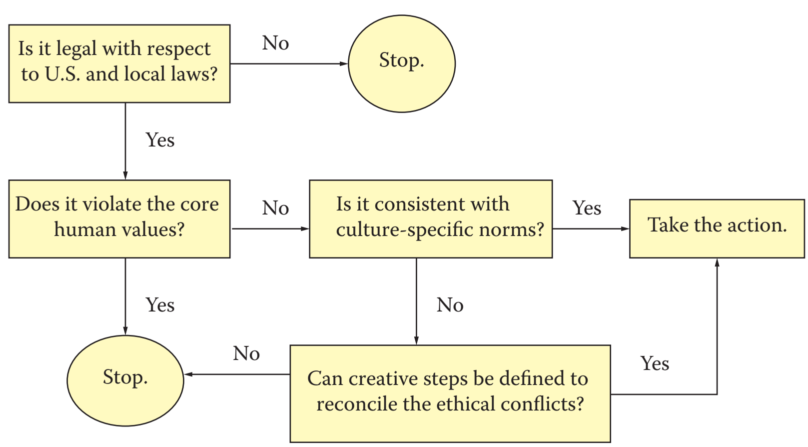

FIGURE 11.5
Decision tree diagram for global ethics problems.

Example 11.4

Your company is among several U.S. suppliers actively competing for a major equipment project of a state-owned enterprise in Shanghai worth about $20 million. You are introduced to a Chinese "consultant" who offers to help. This consultant claims that he has contacts inside the enterprise's midlevel project evaluation teams and its top-level decision-making groups and that he can find out sensitive information for you, such as the equipment design features in the competitor's proposals. He can also relate back to you the enterprise's hints for improvements to your proposal and help move your project along in a multiple-round bidding process. If you do not win, you owe him nothing. However, if your project succeeds, you must pay him 5% of the final project value as a consulting fee. Your peers tell you that such an arrangement is quite normal in China and that a large part of the consulting fee goes directly to staff people in that enterprise and to the enterprise itself. Those who have rejected such help in the past have seen major equipment contracts awarded to less fussy competitors.

What should you do?

Answer 11.4

Some Chinese state-owned enterprises use their own high-level employees to serve as such "consultants," with the ultimate purpose of driving down the final project cost. With the tacit support of the enterprise, each "consultant" forms a team consisting of employees situated in various departments and groups within the enterprise. In offering advice, they pass along information prepared to exert increased competitive pressure among the foreign suppliers. They also collect design intelligence so that the enterprise knows what critical questions to raise in project negotiations. It is one of those tools to help an unsophisticated technological buyer get the bid.

If your company needs the project to penetrate the Chinese market and views the winning of this project to be critically important for your company's future growth in the global market, then you should proceed to engage the consultant, as not doing so will render your company less competitive.

If your company regards this project to be useful, but not critically important to your future success, then stay on the high ground of morality and reject the services of the consultant.

Example 11.5

You are a manager of a joint venture in Russia. One day you discover that your most senior officer in Russia has been "borrowing" equipment from the company and using it in his other businesses. When you confront him, the Russian partner defends his actions. After all, as a part owner of both companies, surely he is entitled to share in the equipment?

How do you propose to resolve this conflict?

(*Source*: S. Puffer and D. J. McCarthy, "Pinning the Common Ground in Russian and American Business Ethics." *California Management Review*, Vol. 37, No. 2, Winter 1995, pp. 29–46.)

Answer 11.5

You should tell the Russian partner that the joint venture would be very happy to assist his other companies in any way. Then you should proceed to send him a bill for lease expenses of the equipment at a commonly accepted market rate. Tell him that, in the future, you would like to preapprove any such leases to make sure that the affected equipment is not needed in your own shop at the time.

11.7 Conclusion

Ethics in the workplace is a fundamental requirement for all members of a corporation—individual employees, managers of working groups, and executives. Everyone must diligently observe universal moral standards, respect basic human values, act legally, conform to local cultural traditions and practices, and disclose the courses of action taken.

Most situations in the workplace involving ethics originate from a conflict between responsibilities and values. These situations must be carefully analyzed by the decision-makers involved to arrive at a proper course of action. A number of models are included in this chapter to assist engineers, managers, and executives in carrying out such analyses.

Creating codes of ethics is helpful. Employees become more sensitive if they are exposed to more real-world cases with ethical implications. Knowing what is right and what is wrong is usually not sufficient in preventing unethical outcomes. Of critical importance to the success of a corporate ethics program is the disciplined enforcement of the code of ethics supported by top management. Good behavior should be recognized and rewarded promptly. Unacceptable behavior must be punished fully and in a timely manner.

The key to ethical behavior is honesty, fairness, and full disclosure. When selecting employees, engineering managers need to focus on their characters, as skills can more readily be updated. Managers themselves need to be technically outstanding, managerially competent, and ethically sensitive.

QUESTIONS

1. Smith, an unemployed engineer who recently received certification as an engineer–intern from the State Board of Registration for Engineers and Land Surveyors, was seeking employment with a consulting firm. Engineer A, a principal with a large consulting firm, contacted Smith. After a long discussion concerning such matters as working conditions, salary, benefits, etc., Engineer A offered, and Smith accepted, a position with the firm. Thereafter, Smith canceled several other job interviews.

   Two days later, in a meeting with other principals of the firm, it was agreed by the firm's management (including Engineer A) that the vacancy should be filled by an engineering technician, not a graduate engineer. A week and a half later, Engineer A contacted Smith and rescinded the firm's offer.

   Did the actions of Engineer A in his relations with Smith constitute unethical conduct? Why, or why not?

   (*Source*: Adopted from the files of the NSPE Board of Ethics Review).

2. As the business manager of your company, you are visiting several companies in Africa to promote new businesses. At the tail end of several successful rounds of negotiation, you are invited to attend a family banquet hosted by one of your potential business partners. This invitation represents a genuine sign of friendship and a commitment to good-faith business dealings in the future.

   Would you be offended if the host wanted you to pay for the food and drinks you enjoyed at the banquet when you depart? Explain your answer.

3. Cindy Jones, a chemical engineer with considerable experience in offset printing processes, was hired recently as an engineering supervisor by Company A. Before

that, she had been working as a research chemist for a competing firm, Company B, where she had invented a new formula and manufacturing process for press blankets. Jones's technique makes the blanket less prone to failure and produces better print quality. These press blankets are being marketed by Company B with great success.

When Jones was hired, there was no discussion about the new offset blanket during the interview. Jones was interested in moving into management; Company A had no openings available, whereas Company B was seeking to add managerial personnel with a superior technical background.

One day, soon after she had started her new job, Jones received an unexpected invitation to a staff meeting from the director of engineering. The meeting agenda focused on the formulas and manufacturing processes for offset blankets.

What should Cindy Jones do?

4. Sara King is a member of the International Union of Operating Engineers. Through the union, she has secured a new job to operate a truck with an end loader at the XYZ Construction Company.

   About two hours into her new job, the truck began to boil because of a leaky radiator. She stopped the truck and went to look for water.

   About 100 feet ahead, Sara spotted a 5 gallon pail. On the way to get the pail, she happened to pass Joe Dow, an old union man, who was tending an air compressor. Joe Dow shouted, "Where are you going?" When Sara told him, Joe Dow replied, "I've got news for you. You are not going to get that pail. Understand? If you want to work on this job, you'd better start acting like a union worker, or I'll report you to the master mechanic. You'd better get back on the truck and wait for the foreman to get a couple of laborers to help you. Remember, if you stop your truck because of a boiling radiator and there's no pail within 40 feet of where you happen to stop, it's not your job to get a container."

   Sara did not want any trouble. So she went back to the truck and waited for the foreman. It was two hours before the foreman came. In the meantime, seven other dump trucks and their drivers were idle. When the foreman finally did come, Sara explained the situation to him. The foreman said, "I'll get you a couple of laborers to draw some water." Sara explained further that she could easily have gotten the water herself earlier, but the operator at the air compressor had told her to lay off. The foreman answered, "That's the way things are on this job. I don't want any trouble, so I do what the union people want."

   Sara encountered other similar incidents as she continued on the job. The basic idea was always the same. Various craft unions decided on a lot of unreasonable restrictions that made a full day's work unproductive. The XYZ Construction Company had entered a cost-plus contract with the client, a steel company. So the more the employees loafed on the job and raised the cost, the more money XYZ Construction Company made. The steel company client was the one bearing the costs. In the long run, the consuming public ended up paying for this labor waste, which contributed to the increasing cost of steel.

   Are there any ethics involved in this problem?

5. Quick Meal is an international fast-food chain that operates in many countries. Company management wants to apply a uniform standard of business ethics, modeled after U.S. practices, to all of its stores worldwide.

   When Quick Meal opened a new store in Country X, initially the local government cooperated fully. Then the government changed hands, and a corrupt group took over. Shortly thereafter, Quick Meal noticed that the general manager of the new store in Country X was providing free food and other concessions to governmental officials "under the table." The general manager was an American married to a local national. He was trying to get an "in" with the new government.

   Store profits were still high, but Quick Meal decided to fire the general manager. The officials of the new government intervened and told Quick Meal to keep him or they would confiscate the local store. Quick Meal stuck to its decision and let the general manager go. The new government followed through with its threats and took away the local store.

   A few years later, the government of Country X changed hands again. Although Quick Meal was promised some indemnity, there was still a considerable financial loss to the company. Despite the fact that these losses were written off, some of the Quick Meal stockholders were unhappy with the company's decision regarding the general manager.

   What should Quick Meal have done?

6. Jane is a member of the board of directors of Power Company Z, which is considering the construction of a new power plant.

   Coal-fired power plants emit sulfur dioxide into the atmosphere. Ambient air containing a high concentration of sulfur dioxide is known to create acid rain, which damages crops and erodes some metals (e.g., nickel and copper). If number 2 oil is used as fuel instead, the sulfur dioxide emission of the power plant could be significantly reduced. However, replacing coal with oil will raise the fuel cost by about 20%.

   Some directors believe that any increased costs would have to be reflected in higher prices. An increase in electricity price would create problems for the company. For example, the Public Utilities Commission may delay approving the proposed rate increase. Consumers may react negatively to the price increase, which could hurt the company's public image.

   Other directors are convinced that the company should not use methods that would increase expenses. They point out that diverse industries and motor vehicles are far more guilty of causing air pollution than the power industry. As one director put it, "Why should we be leaders in this area when it is going to cost either stockholders or consumers a great deal of money?"

   Jane knows that fuel represents only one-seventh of the total cost of generating and distributing electricity. She feels that the company has an obligation to protect public health as long as it can stay reasonably profitable. She believes, further, that the company should not allow purely business considerations to dominate its decisions in an area of such critical importance.

   What do you think Jane should do?

7. Company A recently bought a rock-crushing unit from Company B. This unit was expected to produce 750 tons of crushed rocks per hour, but has in practice been producing only 500 tons per hour.

   Paul, president of Company A, complains to Gordon, sales manager of Company B, about the fact that he is now unable to fill contracts that he secured based on the expected capacity of the machine. In some instances, he has been required to buy crushed rock—at retail prices—to satisfy his contract obligations. Furthermore, he is not able to repay the loan with the expected higher income from the increased production. Paul threatens to sue Company B unless they return half of the purchase price of the equipment.

   Frank, the foreman of Company A's new rock-crushing installation, and Elmer, the company's chief engineer, are not happy with the new equipment. However, they are not sure that company B is at fault. The contract for the new equipment specified that the unit should be able to crush 750 tons of properly graded limestone per hour. Company B had samples supplied by Company A and based its promise of performance on these tests. Paul had been using stone taken from several different company quarries. Both Frank and Elmer had objected to this, since much of this stone was harder than that in the sample given to Company B. The equipment had not broken down, but it was not able to deliver the specified capacity.

   Frank and Elmer discussed this matter and decided to present the problem to Paul. If Company B fought Paul's suit, Frank and Elmer would certainly be called on to testify. Moreover, they both felt that Company B had a right to know that Company A had been using a harder rock than that used in the tests.

   Paul listened to Frank and Elmer, but was not convinced that he ought to inform Company B of the difference in rock hardness. Paul thought that the performance guarantee covered the crushing of rock for any and all of the company's quarries.

   What course of action do you suggest for Company A?

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12

Operational Excellence

12.1 Introduction

Operational excellence (OE) refers to achieving a superior level of productivity in all work processes related to products/services offered by an enterprise (Mitchell 2015). This level of productivity directly affects the customers' overall perception of product/service quality, their tendency to come back for repeat business, and the gross margin realizable by an enterprise. It is thus self-evident that companies ought to constantly strive for achieving excellence in operations.

The work processes involved in the operation of an enterprise include customization, knowledge management, order processing, inquiry coordination, conflict resolution, marketing and sales, product/service production, customer relationship management (CRM), project/program execution, customer support procedures, training of customer-facing agents, product/service delivery process, and so on. The purpose of achieving OE is to slash cost, speed up cycle time, ensure work output quality (right at the very first attempt), eliminate waste, and utilize corporate knowledge efficiently. For a given level of sales revenues (the top line), the attainment of OE will maximize the company's operational margin and consequently its net profits (the bottom line) and the short-term company performance. There are numerous best-practice technologies that can be utilized to achieve OE. Introducing additional innovations to improve these OE practices could put the company further ahead of its existing competitors.

It is, however, worth noting that, despite its importance, emphasizing only OE is usually not enough for any company (Tellis 2013). Companies should also focus on strategic differentiation (see Chapter 10), to promote their long-term health and their sustainable profitability. Both OE and strategic differentiation should be emphasized concurrently. Jack Welch said, "An organization's ability to learn, and translate that learning into action rapidly, is the ultimate competitive advantage." This is especially true when the learning is focused on creating strategic differentiation and OE.

This chapter is organized as follows: First, various industrial best practices related to achieving OE are reviewed (e.g., process standardization and the application of Lean Six Sigma). Commercial software tools that foster productivity are then discussed (e.g., those related to the management of customer relationships, enterprise resources, supply chains, and projects). Also addressed are emerging productivity tools such as web services, service-oriented architecture (SOA), cloud computing, mobile computing, and big data applications. A subsequent section delineates the effective implementation of OE projects, including project selection, justification of financial viability, assessing technical feasibility, securing corporate commitment, project execution, and documentation to preserve lessons learned. Conclusions are then offered.

12.2 Tools for Achieving Operational Excellence

There are a number of technology tools that product/service enterprises may readily adopt for improving their operations.

12.2.1 Process Standardization

A variety of the work processes employed by a product/service enterprise consist of procedures and activities that may be standardized to a great extent. They represent ready-made opportunities for cost reduction, quality improvement, and process optimization to derive OE. Constantly searching for best practices in industries will provide good starting points from which to standardize specific work processes of significance.

Science, technology, engineering, and math (STEM) professionals are expected to diligently implement the engineering management functions of planning, organizing, leading, and controlling regarding their projects, teams, and programs in order to continuously raise work productivity. They should also become aware of distinctive methodologies that could aid in their attempt to achieve OE.

For example, some medical journals (e.g., the *Journal of the American Medical Association* and the *New England Journal of Medicine*) publish well-tested procedures for highly complex medical operations (e.g., open heart surgery and cardiac angioplasty procedure), including elapse time, cost, and death rate. Countless hospitals that adopted such published standard procedures were able to realize cost reductions and save some patient lives. Other medical organizations published checklists for performing complex procedures, in order to minimize medical errors. It is thus useful for all enterprises to diligently search for such tried-and-tested work processes, and quickly implement them. Indeed, many enterprises can improve their fortune by showing diligence in adopting these various best practices. Once they become proficient in applying these processes, they ought to continue to innovate to further advance these best practices.

12.2.2 Productivity Enhancement Programs

12.2.2.1 Lean Six Sigma

Six Sigma is a well-known waste-reduction methodology that has been applied with great success in manufacturing industries (George 2010). It employs the define, measure, analyze, improve, and control (DMAIC) method to improve the quality of standardized work processes. The Lean principle centers on process speed. By emphasizing the flow of information and the interaction between people, Lean Six Sigma can be applied to various processes, such as procurement, accounts receivable, sales, call centers, surgical suites, government offices, R&D, and others to speed up the delivery of high-quality product/service and reduce operations costs to positively affect customers' satisfaction.

Together, Lean and Six Sigma strive to simplify work complexity. This methodology requires that an enterprise follow a well-defined procedure to speed up the work processes and eliminate wastes in delivering products/services. Lean Six Sigma has been demonstrated in many cases to (a) slash product/service costs by 30%–60%, (b) decrease product/service delivery time by 50%, and (c) expand production capacity by 20% without adding manpower. Several successful cases of practicing Lean Six Sigma technologies are published in George (2010), involving companies such as Lockheed Martin, Bank One, City of Fort Wayne, and Stanford Hospitals and Clinics.

Lean Six Sigma may be usefully applied to products/services by following the seven-step procedure that constitutes the mnemonic of our SERVICE model: (1) study customer value, (2) evaluate these product/service elements, (3) refine the work flow diagram, (4) validate and improve on cycle time, (5) institutionalize the drive, (6) call out the complexity, and (7) excel in delivery. Detailed descriptions of this model are included in Appendix 12.7.

The Unity Health Hospital at Rochester, New York, conducted 45 Six Sigma projects that, as of 2011, have resulted in a total saving of $4.5 million. The hospital trained 60 yellow belts and 20 green belts among its staff members and inspired them to constantly search for new projects to promote its OE. The *door-to-balloon* time is an important quality measure in its emergency cardiac care operations. It is the interval that starts with the patient's arrival at the emergency room and ends when a catheter guide wire crosses the culprit lesion in the laboratory. In the past, the hospital was able to meet the industry standard of 90 minutes, as prescribed by the American Heart Association (AHA), only part of the time. After having gone through the Six Sigma process, the door-to-balloon work process was further refined so that the hospital was able to meet the AHA standard 100% of the time for several consecutive years, before this work was reported out to the public.

In many Six Sigma projects, the technique of *value stream mapping* may be beneficially applied. This technique emphasizes studying the specific value that can be added by each activity performed in a process, and simplifying the steps needed to secure the required material and information flows (Martin and Osterling 2013). Utilizing such a technique, Harvard Pilgrim, a health insurance company located in Boston, Massachusetts, made the following decisions: (1) Transfer about 40% of the company's noncore activities to outside vendors. These activities include pharmacy-benefit management, disease management, behavior health management, and claims processing. (2) Engage outside experts to perform data mining analyses in order to discover patients who might be in the early stages of developing heart disease and diabetes, so that these patients could be enrolled in preventive care or disease management programs before their medical conditions become serious. (3) Focus on distinctive activities that confer competitive advantage to the company. These include customer service, design of new services, pricing health insurance, attracting doctors into the network, selling to large customer groups, and marketing to individual policyholders.

In some other cases, the *failure mode and effect analysis* is known to add good value to an operational excellence project. This method catches the potential modes of failures before they actually occur, based on an evaluation by groups of relevant experts (Joint Commission 2010). Analysis and simulation tools may be used to conduct "what-if' studies and define refinement steps. The method may also be engaged to find out the root causes of any product/service defects. For example, the commission's checks of an insurance company were often inaccurate. It turned out that a few root causes were responsible, including, (1) complex commission rules, (2) lack of knowledge on the part of check-processing staff, and (3) confusing procedures for processing checks.

The changes brought about by the Internet are transforming most aspects of service businesses. Besides Six Sigma, the use of Internet-based professional and business software tools, web services, and SOA, which are the subjects reviewed in the following sections, may also be beneficially considered.

12.2.2.2 Web-Based Enablers

All product/service enterprises will generally be expected to perform general activities related to project management, CRM, enterprise resource planning (ERP), and collaboration (Chang 2005a). Many web-based software tools are commercially available to offer assistance in such undertakings. The following lineup offers a sample of these efficiency-enhancement tools:

12.2.2.2.1 Customer Relationship Management

CRM zeros in on the process of understanding and satisfying customers' present and future requirements. STEM professionals are usually engaged in some part of CRM activities (Buttle and Maklan 2015; Peppers and Rogers 2011; Kumar and Reinartz 2012), as related, for example, to product/service customization, problem solving, operational assistance, and other such customer-centered activities.

All customers are important, but some are more important than others, depending on the magnitude of their lifetime value (LTV). LTV is the total sales revenues that could be realized by the company from the purchases made by a customer over the period in which this customer remains engaged with the company. High-LTV customers should be served differently than their low-LTV counterparts.

It is known that a number of U.S. enterprises have set up special corporate desks, each dedicated to selected customer groups and manned by full-time employees who pay personal attention to all of the inquiries initiated by these high-LTV customers. For example, Fidelity Investments offers investment services related to online trades, exchange-traded funds, mutual funds, individual retirement accounts, and 401(k) retirement accounts. Those customers whose portfolio net worth exceeds a specific amount will be invited to join its Private Client Group, which is managed by experienced account executives. At the other end of the spectrum, companies have set up appropriate extranets, so that all low-LTV customers can readily help themselves by accessing web-based resources. Communications links with low-LTV customers may be via e-mail, text chat, web-based callback request, and voice over the Internet. These extranets may contain service catalogs, installation and operational instructions, a frequently asked questions (FAQ) section, a news bulletin, discussion groups, chat rooms, users' groups, and other features. Surveys may be conducted frequently to solicit customer feedback on service quality, desirable new features, suggestions for improvement, and other pertinent issues. Customer service centers are useful in coordinating the inquiries of minor-or medium-LTV customers who prefer human voices. An efficacious customer service center is expected to respond to customer inquiries within a very short period (say roughly 20 minutes).

CRM has gained importance in recent years as a result of competition, globalization, the high cost of customer acquisition, and high customer turnover (Shaw et al. 2010). Surveys point out that U.S. corporations lose one-half of their customers every five years. The following statistics support the importance of this CRM function: (1) it costs five times more to sell to a new customer than to sell to an existing one; (2) a typical dissatisfied customer tells eight to ten people about the bad experience; (3) a company can boost its profit by 85% by increasing its annual customer retention by only 5%; (4) the odds of selling a service to a new customer are 15%; whereas they are 50% with an existing customer, and (5) 70% of complaining customers will do business with the company again if past service deficiencies are quickly corrected.

By managing customer relationships properly, an Internet-enhanced service enterprise hopes to use existing relationships to increase revenue and utilize integrated information to offer an excellent customer experience. The product/service enterprise can also introduce more repeatable sales processes and procedures, conceive new customer value and instill loyalty, and implement a more proactive solution strategy.

Charles Schwab has used a CRM system marketed by Siebel. Table 12.1 delineates the various CRM dimensions. Its specific functions are as follows: (1) Obtain detailed

TABLE 12.1

Dimensions of Customer Relationship Management

Dimension	Customer Relationship Management
Advertising	Provide information in response to specific customer inquiries.
Targeting	Identify and respond to specific customer behaviors and preferences.
Promotions and offering discounts	Tailored individually to the customer.
Distribution channels	Direct or through intermediaries; customer's choice.
Pricing of products and services	Negotiated with each customer.
New product features	Created in response to customer demands.
Measurements used to manage the customer relationship	Customer intention; total value of the individual customer relationship.

information about customers' behaviors, preferences, demands, and buying patterns. (2) Use that information to customize the relationship with the respective customer. (3) Utilize that information to set prices, determine the level of demand and the desires of customers, and negotiate the terms of purchase.

Principal Financial Group, Fidelity Investments, and several other mutual-fund companies have started using web-based e-401(k) programs. The logic for doing so is compelling. When a customer places a phone call to a service center, it costs the company about $9 to respond. This cost is only $2 if the customer gets the required services from an automated voice-mail system. This cost is further reduced to 10 cents if the customer accesses a web-based self-service system.

Autodesk Inc., located in San Rafael, California, is known to have applied an innovative web-enabled corporate help desk to provide high-tech support to customers. The company was able to whittle away the cost associated with internal phone-based support by 70%.

Uniglobe.com, located in Irvine, California, uses a web-enabled call center for travel services. A useful strategy is to build a self-service knowledge base that allows customers to perform self-help activities. Another strategy is to embed e-support capabilities into products, as Hewlett-Packard has done.

iSky (www.isky.com) in Laurel, Maryland, provides an Internet-based, real-time, customer care system that involves customer acquisition, retention, and optimization. It allows end customers to communicate with companies through any available media, such as phone, e-mail, fax, and others. It offers self-help services by accessing the client's e-commerce site and using database and FAQ lookups, automated e-mail, and interactive voice response. It can also move to human assistance by an agent. The human-assisted customer care can be accessed through e-mail, text chat, voice over Internet protocol, telephone callback, and the traditional tele-services support of phone or fax.

Waiting for customers to call for service is not what CRM is all about. The enterprise ought to understand customers, anticipate their future demands, and take action to satisfy those needs. CRM is aimed at determining which customers have the tendency to purchase what types of products and services and taking proactive steps to promote these products/services to them (e.g., cross-selling and upselling in order to derive increased business benefits). CRM could benefit from the use of datamining technologies, by defining customer preferences and characteristics so that products and services can be customized to grow better business results.

12.2.2.2.1.1 Use of Data Mining for CRM Data mining refers to the analysis and nontrivial extraction of information from databases for the purpose of discovering new and valuable knowledge. The knowledge is in the form of patterns and rules derived from relationships between data elements. Data mining emphasizes the use of computationally intensive machine learning tools in the analysis of large and complex databases. As computer-processing speed is being increased constantly, difficult data mining solutions are becoming more readily attainable in a time frame that has become practical to business decision-makers (Lindoff and Berry 2011).

Implementing data mining usually involves the following stages: (1) setting specific goals for data mining efforts; (2) collecting data and defining data types; (3) preparing data, including data segmentation, formatting, and quality control; (4) performing analysis and prediction (employing specific tools such as neural networks, decision trees, logistic expression, and visualization to build predictive models); and (5) conducting measurement and feedback (implementing models to bring forth results and taking corresponding business actions).

Data mining is a useful tool for profiling customers (by segmentation) and predicting their purchasing behaviors (Ahlemeyer-Stubbe and Coleman 2014; Zaki and Meira 2014). Questions explored in data mining analyses may include the following: (1) Who are my best customers, and can I acquire more of them? (2) How can I increase business with my best customers? (3) Who are my worst customers, and should I salvage those relationships? If so, how? (4) Why are some customers leaving? (5) Are there other products or services that I can provide? (6) How can I avoid acquiring unprofitable customers? (7) What are the characteristics of prospective loyal customers? (8) Which products and services are the prospective customers looking at or inquiring about? (9) Which products has a single customer purchased most often? (10) Are there customer complaints about product features, service quality, prices, or other issues?

A case in point is Caterpillar (Lindoff and Berry 2011), which is located in Peoria, Illinois. In 1997, this company set up a database of 100,000 client companies with known purchase records for fleets of truck engines from Caterpillar as well as its competitors. It then defined which client companies would have the best potential to buy from Caterpillar in the future by studying a predictive model based on the use of data mining techniques. Caterpillar initiated a direct-mail campaign to the resulting 10,000–20,000 client companies regarded as having high potential to purchase truck engines from Caterpillar. The resulting response rate to the direct-mail campaign was 37% in 1999, compared with 16% in 1996 and the industrial average of only 3%–5% for similar mailings. The conversion rate of non-Caterpillar clients was around 40%. As a consequence, Caterpillar's truck-engine market share went up to 30.4% in 1999, from 23% in 1997.

In addition, Caterpillar built an intranet to post detailed information about each client company that included all past correspondences. This allowed its national and regional account managers to custom-tailor communications packages online for these individual client companies. All sales proposals for truck-engine packages were web-based. Within 48 hours, a personalized package, complete with the salesperson's signature, could be sent. The Caterpillar case is a good example of how data mining can be applied to serve the business purposes of the company.

Another case of profitably applying data mining techniques is related to the 2012 presidential election. The Obama campaign was said to have hired a docent of data crunchers, who compiled and mined big data comprising merged information collected from posters, fundraisers, field workers, consumer databases, social media, and voter files in the swing states (e.g., Ohio, Florida, Virginia, New Hampshire, Nevada, Colorado, Iowa, Wisconsin, and North Carolina). It included 80 pieces of information about each person (e.g., age, sex, race, and voting history). This team:

1. Conducted multivariate tests to identify issues and positions that could move undecided voters. Studied what policy messages individual voters should hear.
2. Performed simulation tests to predict who might be persuaded by what kinds of appeals. Who might donate online? Who would donate through mail? Subsequently, online donations were a major success. The team helped to raise a total of $1 billion for the campaign.
3. Devised detailed models of swing state voters in order to increase the effectiveness of phone calls, door knocks, direct mailings and the use of social media. Sent messages via "Facebook pal" to promote voter registration and to encourage them to get out to vote.
4. Ran 66,000 tests every night and recommended specific ways to allocate campaign resources for the next day. Discovered the best way to reach targeted voter groups, resulting in buying TV ads by 14% more efficient.

On November 6, 2012, President Obama was reelected, having won all swing states by small margins, with the exception of North Carolina. These data mining efforts were recognized as a key contributing factor to his success. Cracking massive data for insight is the hallmark of our new era involving data mining.

12.2.2.2.2 Enterprise Resources Planning

To achieve sustainable profitability, enterprises need to plan, align, execute, and control all basic business processes. By streamlining all transactions and facilitating data exchange between units, companies can minimize inventories, shorten the cycle time to market, cut costs, upgrade overall operational efficiency, and support customer service. ERP software is designed to integrate into one information system all back-office operations, such as manufacturing, engineering, finance, distribution, procurement, decision support, knowledge management, marketing and sales, and other internal business functions (Monk and Wagner 2012; Leon 2012). This building block is at the foundation of a progressive enterprise. The capability of ERP to integrate business data becomes particularly important to enterprises having numerous sites and multinational operations.

SAP ERP (www.sap.com) is, being a part of the SAP Business suite, a commercial, off-the-shelf ERP software package marketed by SAP, Newtown Square, Pennsylvania. It supports 25 specific functions related to accounting and finance, production planning and material management, human resources, and sales and distribution (Hernandez et al. 2006; Sankar and Rau 2006; Lawlor 2003). It also supports order entry, facilitates supply-planning processes, and assists in customer service. Users of this system claim that the order entry process can be shortened from 18 to 1 day and its financial close cycle from 8 to 4 days. Microsoft is said to have spent 10 months and $25 million on installing mySAP ERP to supervise its 25,000 employees and 50 subsidiaries. It claims to have realized an annual cost reduction of $18 million. Nestle (maker of drinks, sweets, foods, and pharmaceuticals) uses the mySAP ERP application suite to monitor its 498 factories, 210,000 employees, and operations in 69 countries. Rhom & Haas Company spent $300 million in 1999 to convert the company's 64 different information systems to SAP over a four-year period. By 2003, the company was able to trim 4000 workers and save $500 million in operating expenses. It realized an increase in its after-tax profit margin from 2% to 8% by 2005. Other companies that use mySAP ERP include Owens Corning, Colgate-Palmolive, and Warner-Lambert.

Reviewed next are three specific components in enterprise integration systems: (1) procurement resources management, (2) marketing and sales management, and (3) decision support and knowledge management.

12.2.2.2.2.1 Procurement Resources Management Procurement deals with the acquisition of typical operating resources, such as office supplies, services, travel, computer equipment and software, maintenance, repair, and operations (MRO) supplies, fuels, and training. Procurement activities involve identifying and qualifying suppliers, selecting specific products, placing orders, and resolving problems and specific issues after purchase.

Traditional procurement follows a number of manually implemented and time-consuming steps that are subject to frequent human errors. These steps include the following: (1) identify vendors who produce a specific item required by the company and who satisfy a specific set of procurement requirements defined by the company; (2) exchange and review technical documents, such as drawings and product specifications; (3) solicit bids and evaluate available offers; (4) process the purchase orders within the company and obtain approvals; (5) register orders and subsequent payment transactions into the company's back-office systems, involving accounts payable and the factory-receiving department, and (6) resolve human errors and transaction mistakes, such as wrong parts ordered, shipment dates entered incorrectly, and receiving locations improperly specified.

By contrast, web-based procurement makes this process significantly more efficient, decreases administrative costs per item purchased, and is adaptable to the evolution of business models because it can do the following: (1) use online catalogs provided by suppliers; (2) make use of an electronic data interchange (EDI) network to process documents, a network that currently has 400,000 members in active participation; (3) utilize computer-aided design (CAD) software to communicate through drawings; and (4) monitor inventory levels and automate the procurement process.

Online procurement is clearly the current trend. The objectives are to reduce order-processing costs and cycle time, strengthen the corporate procurement capabilities, facilitate self-service, integrate with back-office systems, and raise the strategic importance of procurement.

In newer e-procurement models, *reverse auction* has been advanced as a tactic to procure well-defined items. Reverse auction works in favor of companies that enjoy a dominant buyer's position because of their large transaction volume. Companies engaged in reverse auction first prequalify selected vendors on the basis of product quality, financial strength, company reputation, and other factors. Then they publish the specifications of the goods required and invite prequalified vendors to submit multiple rounds of bids before a predetermined date. The vendor with the lowest bid is awarded the supply contract. It is called reverse auction because the bid price is lowered in each consecutive round. The Internet greatly enables the process of reverse auction.

Microsoft is said to have spent millions of dollars designing MS Market, an online ordering system. It eliminates all paperwork, works in a distributed procurement environment, is particularly suitable for high-volume, low-dollar value transactions, processes orders linked to supply sources, and permits order status tracking. One important advantage of using such a procurement system is the elimination of rules and hidden procedures that greatly slow down the procurement process. MS Market reduces the purchase cycle time from eight to three days and slices overhead costs by about 90%. It averages 100 orders and 6000 transactions per day.

Canadian Imperial Bank of Commerce (CIBC) has 1400 branch offices, 40,000 employees, and 14,000 suppliers. Using a software system marketed by Ariba, Inc. CIBC employees are able to buy standard office supply items online from preferred suppliers. CIBC decreased its procurement costs by 50%.

The following are additional examples of e-procurement software products available in the marketplace:

- *eProcurement* (www.purchasingnet.com) is a web-based procurement software program marketed by PurchasingNet, Inc., a subsidiary of Versata. It streamlines the process of requisitioning, approvals, purchasing management, receiving, inventory control, and catalog management. The company claims that the use of this system has brought about savings of 5%–15% in purchasing costs. A potentially useful application of the software is for the procurement of MRO parts, which are typically low-volume, high-variety, and noncore items.
- *Purchase Manager* (www.Verian.com). Verian Technologies (Charlotte, North Carolina) markets this web-based procurement system, which has a total of eight modules (e.g., item searching, requisitioning, approving, budgeting, purchasing, receiving, managing inventory, and reporting). It automates purchasing with attachments (e.g., drawings and documents), processes orders, updates inventory, issues reports, performs audits, and tracks the status of customer orders. The company claims that use of this software has whittled down its clients' purchase order costs by 80%.

12.2.2.2.2.2 Marketing and Sales Management To service customers well, enterprises should devise an easy order processing system, add value for the customers, increase sales force effectiveness, and coordinate team building. The following processes are readily automated by the use of self-service centers: (1) sales configuration, (2) pricing, (3) quote and proposal generation, (4) commission and contract management, (5) order entry management, and (6) product promotion.

12.2.2.2.2.3 Decision Support and Knowledge Management The functions of decision support and knowledge management are centered on (1) business analysis, such as filtering, reporting, what-if analyses, forecasting, and risk analysis; (2) data capture and storage, including data warehousing, data mining, and query processing; (3) decision support, such as expert systems, case-based reasoning modules, and intelligent knowledge modules; and (4) data dissemination via proper means, including wireless or mobile front ends.

About 70% of Fortune 1000 companies have or will soon possess ERP integration capabilities; among them are Coca-Cola, Cisco, Hershey Foods, Eli Lilly, Alcoa, and Compaq. ERP vendors include SAP, Oracle, PeopleSoft, J. D. Edwards, and Baan.

12.2.2.2.3 Supply Chain Management

Supply chain management involves the formation, maintenance, and monitoring of a complex network of relationships with business partners to secure the required flows of materials, technologies, and information (e.g., demand forecast, order processing, and order status reporting), and finance (credit card information, credit terms, payment schedule, and title ownership arrangements). Its goals are to lessen the time to market, decrease the production cost, and supply the right products/services at the right place and at the right time (Simchi-Levi 2012; Myerson 2012). Achieving these challenging goals requires an integration of various operations, subject to externally imposed constraints, real-time scheduling, and the optimization of multiple-objective functions involving cost, time, service, and quality. Web-based tools are available to assist in dealing with such complex supply chains.

Apple is known to be capable of delivering millions of its sophisticated products very rapidly to multiple markets by having established efficient supply chains with worldwide partners. Boeing is known to have engaged hundreds of contract manufacturers to produce its well-known 787 Dreamliner plastic-body aircrafts, while taking advantage of the resident technological expertise of its suppliers.

Other companies employ web-based technological enablers to drive efficiency, productivity, and competitiveness. There is a wealth of information available. STEM professionals and leaders are advised to follow the literature closely and leave no stone unturned in the quest to find advanced supply chain management tools for productivity improvement and cost cutting.

12.2.2.2.4 Project Management

Project management deals with the management of human and physical resources that are required to attain a well-defined project objective on time and within budget (Kerzner 2014; Heagney 2011). Companies may concentrate on civil construction, capital equipment, research and development, new product or process design, cost reduction, equipment retrofit, quality improvement, customer and market research, and other projects with a high technical content. Project team members may consist of company employees, contractors, suppliers, and/or customers.

Project management has become more difficult as business scopes enlarge, project contents expand beyond organizational boundaries, and project team members reside at geographically dispersed locations. Globalization and new business practices make project variables, such as contractor interfaces and increased uncertainties for on-time and on-budget deliverables, more complicated. A new collaborative work style demands a different project management paradigm—from "command-and-control" to "quick collaboration"—as well as an increased effectiveness that demands just-in-time development and Internet-speed deployment.

The best practices in project management emphasize the following key management issues: tasks and resources, cost, risk, communications, and knowledge.

12.2.2.2.4.1 Task and Resource Management The first and foremost step in managing a project is for the project manager to define the overall project objective and the related budgetary, time, and other constraints, in consultation with company management. In the project-planning phase, tasks are formulated for implementation in parallel or in series, and their starting and completion dates are properly defined. Based on skills, experience, and availability, suitable people are then assigned to these tasks, thereby establishing individual responsibilities and accountabilities. A Gantt chart or project evaluation and review technique (PERT) diagram is then used to graphically model the overall schedule and activities of the project. Tasks on the critical path are subsequently defined, as these should be tracked carefully. At that point, the anticipated completion date and budget for the project are iteratively finalized. The project manager initiates the project after having secured the approval of the project plan from company management and the commitment of all team members involved. The project manager also specifies the communications protocol, guidelines for data and document-transfer, as well as policies related to conflict resolution, problem solving, progress reporting, change management, and other issues. Training sessions are held to ensure that team members can efficiently utilize all the available project management tools.

12.2.2.2.4.2 Cost Management Tools commonly used to manage costs include spreadsheet programs integrated with databases and automatic time entry systems. When incurred, actual expenses related to purchased items and capital assets are reported instantly. The total cumulative cost incurred for the project is then determined and plotted graphically to compare with the planned budget. Progress reports are issued to keep company management informed of the project status. When necessary, remedial actions are initiated in a timely manner to minimize the impact of possible budgetary and other deviations.

12.2.2.2.4.3 Risk Management The successful completion of diverse projects is inherently subject to uncertainties beyond the control of the project manager or team members. Examples of such uncertainties include weather conditions, labor strikes, priority shifts, delays in the delivery of materials, and the unavailability of key team members due to personal emergencies. Forward-thinking project managers need to be aware of the relative impact of such uncertainties and be prepared to respond timely. They are the experts who could "see around the corners."

Most project management software tools permit what-if analyses that determine the overall project outcome (e.g., schedule and budget), when one or more input variables (e.g., task duration, task expenditure, and task initiation date) deviate from the plan, while keeping all remaining input variables unchanged. The results of such analyses allow the project manager to understand the relative sensitivity of the overall project outcome to these specific deviations. By rank ordering potential plan deviations, the project manager is able to proactively devise suitable contingency plans that minimize such adverse impacts on the overall project outcome. Past experience in handling similar projects is helpful to project managers for dealing with this type of project risk.

However, it should be mentioned that a what-if analysis has a fundamental deficiency. It varies only a small number of input variables while keeping a very large number of remaining input variables constant. This deficiency is not consistent with how projects behave in the real world. Real-world projects have uncertainties associated with each and every project input variable, although these uncertainties may be large in some cases and small in others. The overall project outcome model would be a truly realistic one if all input variables were allowed to vary within their respective ranges. The Monte Carlo simulation technique (see Section 6.4.2) is capable of permitting all input variables of a risky project to vary simultaneously (Hult et al. 2012; Yoe 2011).

In recent years, companies in a large number of industries have started to practice the Monte Carlo simulation technique to manage risky projects on personal computers. All input variables may be modeled by a set of three values: the minimum, the most likely, and the maximum. The most likely value of an input variable corresponds to its value as originally planned in the conventional deterministic model, whereas the minimum and maximum values are the variable's possible lower and upper bounds, respectively. For each input variable, its lower and upper bounds should be defined carefully to account for its right range of potential variation. Each input variable is then modeled by a probability distribution function—Triangular, Gaussian, Beta, Poisson, or another—that portrays how the value of this input variable changes with probability. The highest probability is to be assigned to its most likely value. Upon activation of the Monte Carlo simulation technique, all input variables are concurrently varied between their minimum and maximum values. The resulting project outcome (e.g., schedule and budget) is represented by a probability distribution function that has a set of minimum, most likely, and maximum values of its own.

By varying both the minimum and maximum values of specific input variables and the shapes of the distribution functions representing them, the project manager is able to ascertain their relative impacts on the overall project outcome. What the Monte Carlo simulation technique can deliver that the traditional what-if analysis cannot is two pieces of new information: (1) the absolute minimum and maximum values for the overall project outcome and (2) the probability (e.g., 80%) that the project will be completed within a specific budget and on or before a specific completion date. Both pieces of information are valuable to the project manager.

In fact, special cases are readily recovered by using the Monte Carlo simulation analysis. If all input variables are single valued (e.g., setting the minimum and maximum values of all input variables equal to their respective most likely values), then the overall project outcome will also be single valued. This result is equivalent to that delivered by a traditional deterministic project management tool. If one or more input variables are modeled by their three-valued sets while the majority of other input variables remain single valued, then the project outcome will correspond to that of a traditional what-if analysis.

STEM professionals and leaders ought to familiarize themselves with advanced analysis techniques, such as the Monte Carlo simulation technique, which is also readily applicable to other technical subjects involving uncertainties, such as system reliability, technology forecasting, and decision analysis.

12.2.2.2.4.4 Communication Communication between team members is a key success factor for any project. As project numbers increase and project scope expands, team members may become diversified in composition and dispersed in geographical locations. Typical communications tools used will include voice, text, video, data, and documents. Specific Internet-based technologies are to be established to make communication between team members faster, easier, cheaper, of higher quality, and more productive. An open communication policy tends to foster collaboration, which is essential for securing the success of any project.

12.2.2.2.4.5 Knowledge Management Managing knowledge within a project is a task of critical importance. Knowledge is power and it is a decisive and competitive power for a company, if it is created, maintained, and widely applied to add value. At the end of a project, all team members usually gather to give recognition to those who performed well, congratulate each other for the success achieved, and then immediately dash out to take on the next assignment. There may be debriefing meetings that summarize what went well and what did not go so well. In general, preserving the learning from each project is not always done systematically (Dalkir 2011).

Oftentimes, there is a significant amount of knowledge worth preserving. Project management practices that yield positive results should be properly documented. Explicit knowledge is easily preserved and disseminated, but the tacit knowledge, 80% of what we know, is not. Mission-critical data are worth saving. Contingency plans that were successfully activated to eliminate unexpected uncertainties represent valuable corporate know-how that should be recorded. Specific lessons learned from each project should be preserved.

Also important is the preference to store useful knowledge in forms that make it readily reusable, such as searchable databases. Knowledge that is saved to add value, but is not frequently reused, denotes a waste of resources.

Software tools are available to assist in performing various activities related to project management. What capabilities should one look for in a web-based project management tool? Obviously, such tools should assist the project team, whose members may reside in distant locations and work in different time zones, in accomplishing the project objectives in time and within budget, while facilitating instant communications and data sharing. England and Finney (2007) offer a set of selection guidelines for web-based project management tools. According to them, a good web-based project management tool should be able to do the following: (1) Offer easy access to the project status of assignments, costs, and the time line in real time, via a browser-based client. (2) Have a portal for project-related information. (3) Be capable of importing data from and exporting to other project management tools. (4) Run programs on a web server. (5) Manage contact information about every team member. (6) Map projects and assign tasks to team members (Gantt charts, histograms, and PERT charts). (7) Assign different views to allow each team member to see only the information and assignments pertinent to him or her. (8) Enable members to update tasks, add notes to tasks, attach files to the document, and send e-mails to others. (9) Permit easy installation and use. Offer sample templates for specific project topics that are readily modified to fit the needs of individuals. (10) Possess the capability to track any number of tasks and milestones with associated links to web sites, documents, and every other project. (11) Hold online, text-based chats for virtual meetings or threaded discussions for collaboration between team members. (12) Track resources allocation—load-leveling capabilities and membership rosters integrated with external directories. (13) Organize user interfaces. (14) Perform scenario analyses (what-if). (15) Enable risk-adjusted modeling. (16) Document project outcome and learning.

Project management software tools have migrated from the infrastructure of centralized minicomputers, to PC desktops and local area networks (LAN), and, finally, to web-based tools (Laudon and Traver 2014). In the web environment, project management tools involve the following: (1) e-mail, (2) web pages to increase speed and availability of information, (3) groupware for project tracking and scheduling, (4) file transfer protocol (FTP) for transmission of documents and data, (5) shared databases of multimedia formats, (6) remote accessibility, and (7) integration with wireless and palm-top technologies There are still two significant constraints currently present in web-based project management tools, namely, bandwidths and infrastructure for multimedia transmission and data security.

Project management tools are advancing steadily. Enumerated next are some of the key project management tools available to date:

1. *Primavera P6 Professional Project Management* (www.oracle.com). This project management software is marketed by Oracle, Redwood Shores, California. It has several modules useful for project management, including Project Planner to oversee activities and resources, PrimeContract to monitor costs, Evolve to manage the portfolio, and TeamPlay to promote the collaboration of participants.

   Toronto Transportation Commission (Toronto, Canada) successfully applied Project Planner by Primavera to manage 50 construction service projects, each worth \$2 million to \$1 billion and having 100–600 activities, involving a total of 9000 people. A single master schedule is updated across a series of personal computers linked to four servers on a local area network (LAN). Data are then converted to PERT charts and distributed to all involved. The software displays the links between each project and its associated activities. Communications are enabled by e-mail, web pages, and other forms of Internet-based tools to keep everyone focused on the project goals. Resources to be deployed are categorized by discipline, workload, work hours available, and planned work to optimize resource loading for meeting project deadlines. Report generation may be in the form of paper, e-mail, and posting on TV or the web. Data can be used for risk management purposes. The software allows project managers to keep in mind the big picture of all of their projects without getting lost in the details, but it also permits them to drill down for details if desired.

Dick Corporation (Pittsburgh, Pennsylvania) utilized Primavera's Project Planner to manage the construction of a 115,000 square-foot addition to St. Francis Health System Hospital while the hospital was still operating. The software assisted in scheduling and coordinating all pertinent resources, including contractors, hospital personnel, and special equipment.

2. *McLaren Collaboration Workspace CW* (www.mclarensoftware.com). McLaren Software in San Francisco markets this software, which provides an online collaboration workspace particularly suitable for managing construction projects in the building industry. Built on the Oracle database using Application Server 3.0 operating in a Windows environment, this software plans actions; tracks activities; coordinates the work of engineers, architects, and contractors; and automates various project components. Team members are connected to a password-protected website that contains project documentation, schedules, drawings, charts, and other project data files. Project managers have access to a messaging system and can monitor communications between team members.

   This software has been used by the San Francisco Public Works Department, Sun Microsystems, Stanford University, Fidelity Investment, and Charles Schwab.

3. *ProjectGrid* (www.ProjectGrid.com). This software of ProjectGrid.com, Inc., Columbus, Ohio, provides websites on a subscription basis to host project-specific information. It functions as an online communications management tool for project management activities. It is capable of managing (1) financial information, (2) bid calendars, (3) project schedules, (4) work in progress, (5) site visit reports, (6) design drawings, (7) change orders, (8) contract invoices, (9) file downloads, (10) contract information, (11) administrative functions, (12) digital photo logs, and (13) other data. Team members access a password-secured website to receive updated project information. This program may be particularly attractive to small and midsize companies.

4. *ProjectTalk* (www.projectTalk.com) software by Meridian Systems (Folsom, California) has five modules to aid in construction project management: (1) document management, (2) cost control, (3) field management, (4) purchasing control, and (5) reports and queries. Through browsers, team members can access design drawings, job-site photos, project schedules, and over 400 reports. They are linkable to "e-commerce" and "collaboration" modules of Projecttalk.com to promote web-based communication and collaboration among team members. It is regarded as a standard in the architects, engineering, and construction (AEC) industry and is widely used by architects, engineers, general contractors, and public institutions.

5. *Elite 3E* (www.elite.com). This financial and practice management tool by elite.com (Los Angles, California) connects team members with subcontractors and clients. It can be accessed via standard web browsers and wireless palm connections. It does full project budgeting, tracking, and reporting, and claims to be easy to learn and convenient to use. It offers convenient access to subcontractors and clients and can be activated through subscription.

6. *Microsoft Professional 2016* (www.microsoft.com). Its capabilities include (1) creating Gantt charts for project and individual team members, (2) handling multiple project tasks and time lines, (3) producing summary reports, (4) updating project status and information using "time sheets," and (5) offering online help and tutorials (Chatfield and Johnson 2013). Team members can access project information and view Gantt charts, multiple project tasks, time lines, and summary reports through a standard web browser. Project status information can be updated through time sheets that permit authorized team members to add tasks for themselves or others. Rules can be entered that, when triggered, will alert the project manager of unexpected deviations from the plan.
7. *Others*. Additional project management tools include: TeamCenter Project by Siemens (www.plm.automation.siemens.com/en_us).

As evidenced by the preceding discussion, numerous web-based project management tools are strong in some aspects and weak in others. There appears to be no single tool that is capable of satisfying all project management requirements. A growing trend in the field of project management is to lease advanced tools to manage specific projects on a "pay-as-you use" basis. Some application service providers (ASPs) market web-based project management tools. In general, leasing project management tools is more cost-effective, as it meets the specific project requirements better and consumes less cycle time for the company, compared with the option of either buying expensive software tools that have to be customized or building them in-house.

12.2.3 Emerging Tools

12.2.3.1 Web Services

In recent years, web services have become increasingly popular as a computing concept (Papazoglou 2012; Zhang 2011; Alonso et al. 2010). In general, web services have several common components that make them capable of interacting with human users or with other applications: (1) Simple Object Access Protocol (SOAP) provides the envelope for sending the web services messages. (2) The Web Services Definition Language (WSDL) forms the basis for web services. A service provider describes its web services using WSDL (e.g., XML, Java, and others). (3) Universal Description, Discovery, and Integration (UDDI). Registries can be searched to find and use web services quickly, easily and dynamically.

There are two specific types of web services. The first type is associated with application services that are delivered to human users over the web. The second type is related to applications modules that are made accessible to other applications over the Internet through XML-based protocols.

Several IT organizations have started offering the first type of web services. Amazon, Sun Microsystems, Microsoft, Salesforce.com, and others are known to be vendors of such services (Huckman et al. 2008), namely,

- *Storage*. Simple Storage Service (S3) by Amazon provides a basic interface for storing and retrieving data from anywhere on the web. To ensure secure storage, each object uploaded to S3 will be duplicated and multiple copies are stored in multiple locations.

- *Computing*. Elastic Cloud Computing (EC2) by Amazon is a web service that provided resizable computing capacity in the cloud. Clients could run programs on Amazon's computers.

  The Sun Grid utility services offered by Sun Microsystems provide clients with computing power, also on a pay-as-you-go basis.
- *Database*. SimpleDB by Amazon enables real-time lookup and query of structured data.
- *Simple queue service (SQS)*. SQS, provided by Amazon, is a scalable, hosted queue, which can be used to store data messages sent between applications, thus allowing clients to move data between application components that perform different tasks. In other words, it allows components of an application to send messages to other components and establish a place to store these SQS requests and have the consuming components pick them up.
- *Flexible payment services* (FPS). This service is offered by Amazon for clients to collect funds from their customers using credit cards, while allowing the clients to define payment conditions.
- *Online marketplace*. Salesforce.com offers Exchange as an online marketplace, allowing clients to swap and sell applications. It covers the modules sales service, marketing, and partners.
- *Build and host web applications*. Google offers App Engine, which allows clients to build and host web applications on Google's scalable infrastructure. Windows Live by Microsoft offers the service of an e-mail program, news headlines, blog and audio feeds, and a web page builder.
- *Premium support*. Assistance is offered by Amazon to clients regarding services on S3, EC2 and SQS.

In addition, companies such as IBM, Sun Microsystems, and Hewlett-Packard offer web-based infrastructure and software solutions to business clients. The proper use of these types of Internet-based technology services will likely to raise the operational productivity of many service enterprises.

The second type of web services deals with creating modularized applications that interact with other modularized applications, following specific standards regarding language, data description, data exchange, and connection protocols. Because everyone shares the same standards, these modularized applications are able to talk freely with other applications (McAfee 2005). Thus, this second type of web services allows the construction of modular and interchangeable building blocks of software, which are most useful as the basic layer components of an SOA, as will be reviewed in Section 12.2.3.2.

12.2.3.2 Service-Oriented Architecture

Since 2003, SOA and web services have become an important new development in the distributed computing world. Innumerable publications in the literature envisage the business value that may be conferred by employing this new and emergent computing approach (Ortiz and Tran 2015; Josutti 2007; Bell 2010; Erl et al. 2012).

It is important for STEM professionals and leaders to understand how SOA is defined, what elements SOA is composed of, what benefits and risks might be involved in the implementation of SOA, which SOA applications cases have become available,

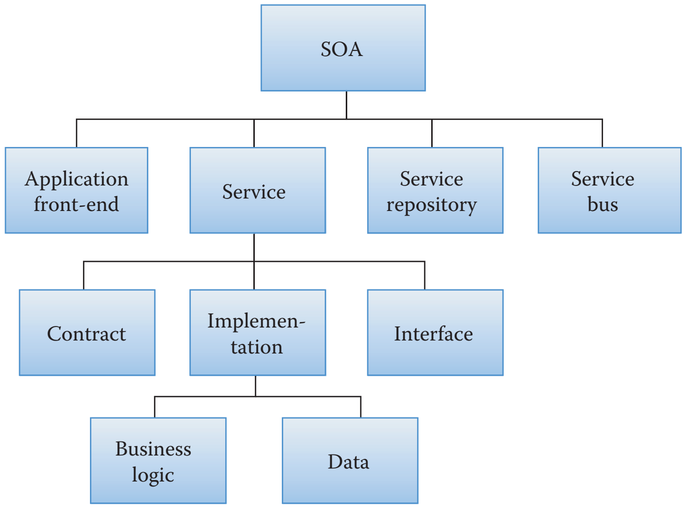

FIGURE 12.1
Structural elements of an SOA.

and, above all, what might be the potential impact of SOA on OE to products/services enterprises.

In the literature, SOA has been defined by different people in different ways (Erickson and Siau 2008). Currently, there is no consensus among various groups regarding a unified definition for SOA. SOA is defined from a technological standpoint in Krafig et al. (2004), as a service architecture that is based on the key concepts of an application front end, service, service repository, and service bus. A service consists of a contract, one or more interfaces, and an implementation. Accordingly, SOA may have up to four layers, as illustrated in Figure 12.1.

1. *Enterprise layer*: Application front ends (for communicating with end users) and public enterprise services (enabling cross-enterprise integration)
2. *Process layer*: Containing process-centric services
3. *Intermediary layer*: Providing technological gateways, facades, and adapters
4. *Basic layers*: Providing the basic services of the SOA (business logic, data, proxies for other company's public enterprise services)

An SOA structure for airlines (a fully developed SOA with four layers) is depicted in Figure 12.2.

XML-based web services (based on SOAP and WSDL) are not the only viable technology platform for an SOA, which is generally not dependent on any particular technology platform.

Erl et al. (2014) offers the following definition for SOA: "SOA establishes an architectural model that aims to enhance the efficiency, agility, and productivity of an enterprise by positioning services as the primary means through which solution logic is represented in support of the realization of strategic goals associated with service-oriented computing." This definition seems to encompass the various common elements contained in various definitions proposed by others. It tends to emphasize the commonality among them. It appears to be the best broad-based description of what SOA is all about.

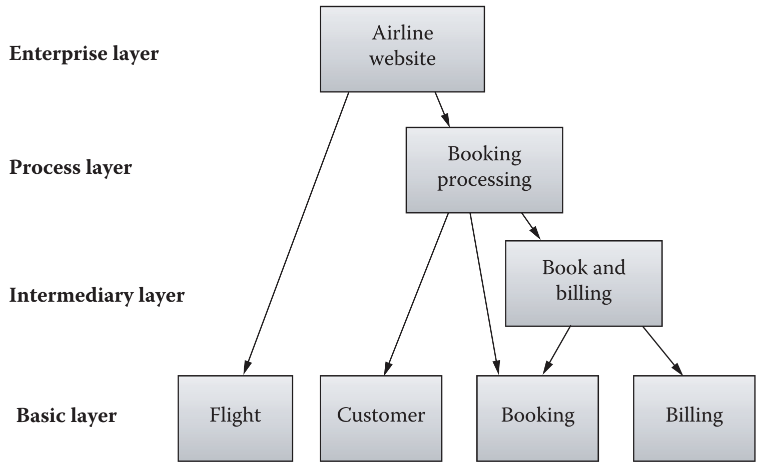

FIGURE 12.2
SOA for airlines.

SOA contains three principal elements, according to Carr (2005). (1) *Virtualization*. It eliminates the platform-related restrictions to allow applications to run on different platforms. (2) *Grid computing*. It allows a number of diverse hardware components (servers, disk drivers, etc.) to interact readily and to form an operating unit. (3) *Web services*. It ensures smooth interactions of legacy and new software by standardizing the interface between applications (e.g., input format, language of transmitting messages, and other interfacing protocols), thus turning them into modules that can be assembled and disassembled readily.

As a result, SOA is expected to deliver the following useful functionalities:

(1) *Composite applications*. SOA supports the creation of composite applications that bring together numerous business processes from multiple systems into a simple user interface. With SOA, companies will be empowered to change business processes with greater confidence, predictability, and frequency, leading to better agility and performance. The services provided by vendors are shared among applications. Web services create a common platform that enables SOA. (2) *Agility*. With SOA, change inherently becomes faster and easier, because the architecture is centered on the concept of services that are designed to be interoperable and used across different business processes and variable business contexts. (3) *Reusability*. The service-oriented approach delivers IT systems as a set of reusable services that can be assembled easily to deliver a composite application that automates a business process. This "assembly approach" accelerates the time to market for new applications and minimizes IT costs. SOA allows service components to be reused across the organization and reassembled on the fly. In so doing, SOA enables rapid responses to business and technology changes in the marketplace.

To minimize the operating risks associated with the implementation of SOA computing, there are five phases of SOA implementation that must be managed properly: (1) Define the desirable future state and the roadmap to achieve it (e.g., set the vision and plan the project). (2) Design an initial set of enterprise software services with obvious business values and impact to gain corporate acceptance. (3) Set up a library of enterprise services that are useful to the vast majority of corporate users. (4) Institutionalize the SOA program to further align with the business organization. (5) Continue to innovate in order to enhance the value of SOA to the organization.

STEM professionals and managers who are interested in becoming versed in the computational and technological issues related to SOA design and implementation should consult the Prentice Hall Service-Oriented Computing Series from Thomas Erl, which includes (1) concepts, technology, and design; (2) service design; (3) service pattern; and (4) design and versioning, as well as other suitable technology resources.

Because of the aforementioned set of functionalities, SOA is expected to offer a number of benefits to its corporate users: (1) Foster time to market for new applications and help organizations achieve competitive advantage by rapidly seizing new opportunities and responding to unexpected threats. A reduction in the time required to deliver new services is made possible by the highly reconfigurable implementation of business processes. (2) Flexible applications inspire the introduction of flexible business processes, making the organization more agile and adaptable to the pace of changing business environments. The integration of applications is streamlined. (3) Service reuse brings about greater efficiency and lowers maintenance costs, making IT more efficient in supporting business initiatives. A better utilization of company resources is ensured by the reuse of existing software assets. (4) The ability to respond quickly to new regulatory requirements or specific compliance issues helps companies avoid governmental penalties.

These potential benefits are directly useful to product/service enterprises that strive to achieve OE.

SOA is a mainstream IT initiative. However, it may fail due to a number of deficiencies enumerated here, some of which are management centered. (1) Failure to communicate properly to enable the wide use of SOA by everyone. (2) Lack of trust in the quality offered by the SOA software involved. (3) Insufficient and difficult testing of SOA components. An insufficiently tested but reusable service can amplify risks, as a failure in a crucial service can ripple through all the applications and other services that access it. Thus, proper testing of services is a critical requirement with respect to functionality, performance, security policies, interoperability, and boundary conditions. (4) Service-level agreement between providers and consumers. (5) Change of service infrastructure has an impact on the availability and performance of the service. (6) Requirements for services are not clearly visible. (7) Services designed are not properly governed and designed for reuse. (8) Support personnel is lacking.

Quite a few of these identified deficiencies are related to project management. Service professionals and leaders should pay attention to them when implementing SOA.

Rogers (2008) conducted a survey among IT managers and enterprise architects to define the critical success factors for an SOA program: (1) *Business alignment*. Center on enterprise business goals and strategies, business support and involvement, and value measurement, and align the funding model. (2) *Organizational change management.* Align resources, implement recognition/incentive program, skills, and education. (3) *Communications*. Communications are necessary for advocacy, awareness, visibility, discovery, and progress reporting. (4) *Trust.* Trust is key for performance, availability, service reliability, security, and quality. (5) *Architecture*. Institutionalize enterprise SOA reference architecture and standards. Implement cross-enterprise services management discipline. (6) *Scale and sustainability*. This includes SOA program scalability, technical scalability, and service granularity. (7) *Governance*. Introduce a strong SOA governance program at the early stages of initiative, integrate SOA and overall IT governance processes, specify runtime practices and design policies, and define and assign key roles and responsibilities.

It is rather clear from these success factors that it takes a determined corporate commitment to pursue SOA initiatives and to achieve a useful outcome.

A European-based telecommunications and Internet provider doubled its corporate size in 2005 by merging with two other companies. The organization wanted to become more flexible in managing its business lines, reducing staff costs, and ensuring high levels of subscriber support. Hewlett-Packard, one of several major SOA service providers, implemented HP SOA Management and HP SOA Systinet programs to better align the company's IT project management and the organizations' business strategies. The SOA initiative was focused on managing its assets and monitoring service performance. The following programs were introduced:

- HP SOA Systinet: Governance
- HP SOA Policy Enforcer and HP Diagnostics: Service monitoring
- HP Business Availability Center for SOA: Service availability

The benefits realized include: (a) 33% increase in services uptime, (b) 50% reduction in time to market for new services, and (c) 30% savings in total service management costs. The average annual benefits had been in excess of $5,900,000 (Anonymous 2008). Krafzig et al. (2004) contains additional SOA application cases of interest in the service industry, including (1) Deutsche Post AG (German post office), (2) Winterthur Group (insurance), (3) Credit Suisse (financial services), and (4) Halifax Bank of Scotland (financial services). Interested readers should consult these references.

Currently, countless service companies have invested in building and maintaining in-house computer facilities to provide the required business analysis and other computing activities in support of their business objectives. In the future, such computing needs may be satisfied by running software hosted by prominent vendors. This is similar to today's industrial and residential consumers who buy electricity from electric utilities, rather than producing electricity with their own small-scale generators.

Proponents of SOA technology predict that there will be an IT utility, similar to the electric utility industry, from which service enterprises would "buy" or "rent" selected computing service packages, instead of each maintaining its own data centers and creating specific software application modules. This SOA approach will expedite the end of corporate computing (Carr 2005), because of its obvious impact on costs, speed, and process flexibility of business computing. Because of its flexible and logical design architecture, SOA has a pretty bright future. SOA is likely to make service enterprise more cost-efficient, productive, and fast responding in a highly competitive marketplace.

12.2.3.3 Cloud Computing

Cloud computing (Helfert et al. 2014) is a service concept, by which client companies and individual customers are able to "rent" computing services from specific vendor companies that are capable of accessing distributed and unused computing assets. This is especially important when a service enterprise is in need of such on-demand and "pay-as-you use" computing power, which exceeds its in-house capabilities.

The computing world is continuing its evolutional changes, from mainframe to minicomputers, to desktop personal computers, and now to the era of personalized computers, through the massive use of tablets and smartphones. The cloud, like a mainframe in the sky, is capable of delivering personalized, distributed computing efficiently. Users may access their personal clouds using a variety of Internet-connected gateway screens or devices.

As of now, Apple has its iCloud solution, which can store pictures, music, movies, and other files in the cloud for ready access by the users. Amazon and Google are known to have similar services in development. Other screens to connect to the cloud are very likely to become available in the future.

12.2.3.4 Mobile Computing

Mobile computing (Kumar et al. 2012) refers to a computing environment with physical mobility such that users are enabled to access data, information, or other logical objects from any device and in any network, while on the move. It allows a user to perform a task from anywhere using a computing device in the public (the web), corporate (business information), and personal information spaces (medical records, address book). The functions of mobile computing include the mobility of user, network, bearer, device, session, service, and host. Access to information and virtual objects through mobile computing enables the optimal use of resources and thus results in increased productivity. In addition, mobile computing is becoming increasingly useful, as reaching customers via their movable communications devices adds the factor of convenience to the customer experience.

12.2.4 Big Data

Big data are high-volume, high-velocity and/or high-variety information assets that require new ways of processing (e.g., massively parallel software running on thousands of servers) in order to inform decision-making, discover insights, and pursue process optimization. (Beyer and Douglas 2012). Examples of such data sets include web logs, social networks, social data, Internet text and documents, Internet search indexing, call detail records, medical records, large-scale e-commerce, photography archives, and video archives. In addition, the amount of traffic flowing over the Internet is projected to have reached 669 exabytes by 2013. Wal-Mart is said to handle more than one million customer transactions every hour, which are imported into databases estimated to contain more than 2.5 petabytes of data—the equivalent of 167 times the information contained in all the books in the U.S. Library of Congress (*The Economist* 2010).

Developed economies make increasing use of data-intensive technologies. As big data represents a rich source of information, which could be mined to foster competitive advantages, its systematic use will have an important impact on services in the future.

The IBM Watson supercomputer won the *Jeopardy!* game show on February 16–18, 2011, against two of the best-known human experts. This represented a significant breakthrough in natural language interface, data process, and self-learning. Soon after this victory, IBM signed a contract with Wellpoint Inc. to process massive amounts of patient databases (e.g., medical history, genetics, biometric fluctuation, and other factors), in order to assist physicians and nurses in arriving at more accurate and evidence-based diagnosis and treatment options. In 2012, Citibank engaged IBM to utilize its Watson technology for analyzing customer data, with the purpose of offering new personalized banking services centered on the customer's digital and mobile lifestyles.

In 2015, IBM established a new business unit called Watson Heath to focus on the development of new applications of Watson technologies in health care, taking advantage of various empirical rules and heuristics in the medical fields.

Such a new technology, once further perfected, could likely raise corporate performance in various fields, which are enabled by rapid case evaluations. Additional future applications may reach data-intensive service sections, such as radiology, legal, financial, engineering, retail, and professional business and engineering consulting.

12.3 Implementation of Operational Excellence

In order to achieve OE, enterprises are recommended to select the projects, evaluate their financial viability, and check the technical feasibilities in view of the resources available, before going forward with the project implementation. It is highly advisable that these steps be implemented systematically.

12.3.1 Selection of OE Projects

These projects should be selected primarily to influence the customer's perception of the service offered. Preference should be given to advancing processes and work activities that are involved in service customization procedure, new service codevelopment, customer problem solving, service support programs, customer access to service information, management of service supply chains, and others concentrating on constantly improving the value of supplemental service elements to customers. Specifically: (1) Assuring competitive advantages by utilizing corporate know-how to customize service and to bring about value beyond the customer's expectations. (2) Streamlining those processes that allow customer-facing agents to rapidly access corporate knowledge when servicing customers. (3) Management of customer-centered projects, including access to in-house and external resources. (4) Customer support processes (e.g., web pages, call centers). (5) Business processes, such as marketing and customer management, including the collection and processing of customer feedback. (6) Other internal business processes, such as order entries, invoicing, financial control, supply chain management, and production.

12.3.2 Financial Viability of Selected OE Projects

Once a specific OE project is defined, its financial viability should be convincingly demonstrated before seeking managerial approval for implementation. Such a project may require the following resources: (1) Capital investments related to the use of the OE tools (e.g., Lean Six Sigma, web service, or SOA development). (2) Maintenance expenditure for the selected OE tools. (3) Employee training costs and expenses of new hires, if any. (4) Projected reduction of operations costs. (5) Projected life of the OE project in years. (6) Cost of money.

Let us assume that a business unit (e.g., department, regional organization or the whole service enterprise) is considering the deployment of a specific OE tool. Table 12.2 displays its multiple-year income statement before the introduction of such a tool, the base case. The number of years assumed in this income statement should be compatible with the time span, during which the OE tool is expected to remain effective. This base case is to be set up following the methods indicated in Chapter 7.

Table 12.3 shows the multiple-year income statement of the same business unit, but including the financial impact derived from the use of the OE tool, the improved case. An investment of $1,500,000 is assumed to be required to initiate this OE project and the estimated reduction in operations expenses is 20% (Row 4). Obviously, the estimated cost

TABLE 12.2

Service Enterprise Current Operation (Base Case)

		A	B	C	D	E	F	G
	Base Case	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6
1	Revenue		42,074	51,346	56,551	58,041	59,570	61,357
2	CGS	—	31,555	38,509	42,413	43,531	44,678	46,018
3	Gross margin	—	10,519	12,837	14,138	14,510	14,892	15,339
4	Operating expenses	—	3,786	4,621	5,090	5,224	5,361	5,522
5	Depreciation	—	4,140	4,140	4,140	4,140	4,140	4,140
6	EBIT	—	2,593	4,076	4,908	5,146	5,391	5,677
7	Taxes at 40%	—	1,037	1,630	1,963	2,058	2,156	2,271
8	EBIAT	—	1,556	2,446	2,945	3,088	3,235	3,406
9	Net cash flow	—	5,696	6,586	7,085	7,228	7,375	7,546
10	Discount factor	—	0.9259	0.8573	0.7938	0.7350	0.6806	0.6301
11	Discount cash flow	—	5,274	5,646	5,624	5,312	5,019	4,755
12	PV (cash flow)	31,630	—	—	—	—	—	—

Notes: Unit: Thousands of dollars. Cost of money = 0.08.

TABLE 12.3

Service Enterprise Current Operation (Improved Case)

		A	B	C	D	E	F	G
	Case with 20% Improvement	**Year 0**	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Year 6**
1	Revenue	—	42,074	51,346	56,551	58,041	59,570	61,357
2	CGS	—	31,555	38,509	42,413	43,531	44,678	46,018
3	Gross margin	—	10,519	12,837	14,138	14,510	14,892	15,339
4	Operating expenses (–20%)	—	3,028	3,697	4,072	4,179	4,289	4,418
5	Depreciation	—	4,140	4,140	4,140	4,140	4,140	4,140
6	EBIT	—	3,351	5,000	5,926	6,191	6,463	6,781
7	Taxes at 40%	—	1,340	2,000	2,370	2,476	2,585	2,712
8	EBIAT	—	2,011	3,000	3,556	3,715	3,878	4,069
9	Net cash flow	—	6,151	7,140	7,696	7,855	8,018	8,209
10	Discount factor	—	0.9259	0.8573	0.7938	0.7350	0.6806	0.6301
11	Discount cash flow	—	5,695	6,121	6,109	5,773	5,457	5,172
12	PV (cash flow)	34,327	—	—	—	—	—	—
13	Net gain over project life	2,697	—	—	—	—	—	—
14	Investment	1,500	—	—	—	—	—	—
15	Net gain	1,197	—	—	—	—	—	—

Notes: Unit: Thousands of dollars. Cost of capital = 0.08.

reduction must be convincingly verified using past cases. Again, the present value of its cash flow is then calculated.

Tables 12.2 and 12.3 indicate that the present value of cash flow for the improved case is $34,327,000, whereas that of the base case is $31,630,000, an increase of $2,697,000. However, subtracting the assumed investment of $1,500,000 from this increase, the net gain for this example case turns out to be $1,197,000. This net gain number must be positive for any OE project to be worth implementing in the first place. Of course, the higher this net gain number, which represents the net economic value added, the more valuable the OE project will be to the enterprise.

Additional details of such multiple-year income statements are explained in Chang (2005b), as well as in any financial accounting textbook (Libby et al. 2013).

12.3.3 Technical Feasibility

After the financial viability of the OE project is proved, it is also useful to review the question of technical feasibility during the planning stage. Can the project be implemented based on the available people, schedule, technological tools, financial resources, and managerial attention? Some technological tools (e.g., the previously described web-based enablers) need to be acquired, installed, and customized before they can be efficiently utilized. Staff should be properly trained for them to contribute to the project.

The answer to this feasibility question should be yes before the project is approved for implementation.

12.3.4 Management Commitment

It is important to ensure the commitment of the enterprise in terms of alignment with business objectives, definition of specific project goals, appointment of a project leader, allocation of resources, and project time lines before the initiation of an OE project.

12.3.5 Project Execution

An approved OE project delivers value only when it is implemented properly by having achieved its stated objective on time and within the allocated budget. Activities involved in this phase include planning, resource allocation, task organization, progress monitoring, and problem and conflict resolution. Commercial project management tools may be used to facilitate these activities.

Products/service enterprises favor leaders who are well versed in securing corporate commitment, defining project objectives, scheduling tasks and people, promoting team collaboration, resolving conflicts, managing uncertainties, controlling quality, planning for unexpected contingencies, monitoring tightly all tasks on the critical path, making midcourse corrections, if needed, and securing customer feedback.

Seeking customer feedback is useful to gauge the degree of project usefulness to the intended users. This is to allow a continuous betterment of future projects. Advanced tools for managing projects should be engaged to guide the implementation of complex projects, to promote (a) project transparencies, (b) fast access to data, (c) rapid communication to allow quick decision-making, and (d) recordkeeping and knowledge management.

12.3.6 Documentation and Lessons Preservation

At the completion of an OE project, a comprehensive project report should be prepared to include: (a) a summary of results and review comments, (b) unique experiences acquired, (c) lessons learned, and (d) insights garnered. This is to make sure that what is learned in this project could be applied to other projects in the future and that the enterprise continues to accumulate useful insights and becomes smarter over time.

STEM professionals should strive to initiate new OE projects on a regular basis by identifying new opportunities to whittle down costs, reduce cycle time, increase customer value, justify them financially, and execute them in time and within budget. It would be useful to aim at improving these operations by, say, 5% or more every year.

12.3.7 Organizational Resizing due to Operational Excellence

Success in achieving laudable results in OE could cause some employees to become redundant. If employees who work hard to actively contribute to improve efficiency and productivity are not being properly taken care of, they will feel betrayed, leading to a deterioration in the morale of surviving employees, which in turn could trigger voluntary turnover, possibly causing the organization to be deprived of the critical skills and tacit knowledge needed to continue pursuing OE (see Smith 2011).

Also of concern is the potential work overload of surviving employees due to an efficiency-induced organizational resizing. A case in point is Red Lobster, which in 2011 required its waitresses to serve four tables, instead of the original three, while cutting food walkers at the same time. The company had to reverse this productivity improvement policy in 2013, after having registered employee complaints, customer dissatisfaction, and a sizable reduction in business.

Service companies may initiate the following few steps, known in the industry, to minimize such adverse consequence:

1. *Create* new job opportunities to absorb these people, such as (a) initiating new services developed by the company's strategic differentiation efforts; (b) expanding the activities of new technology or business units acquired by the company, if available; (c) jobs opened up in business units spanned off from the company; (d) jobs made available internally due to work redesign for creating new value to customers; (e) opportunities due to entering new markets to serve new customers; and others.
2. *Maintain* an up-to-date inventory of needed skills and capabilities and train all employees, possibly by Internet-based tools, to enable their transition into new job assignments. Plan well to avoid overloading surviving employees with excessive work.
3. *Implement* knowledge management programs to preserve, update, and reuse critical insights and tacit knowledge for enhancing corporate competitiveness in a systematic manner.
4. *Communicate* clearly that the organization must periodically adjust its size to meet the ever-changing needs dictated by technological advancement, service innovations, marketplace competition, and shifting customer demands. The company would also devise a long-term plan for implementing the right organizational resizing program when needed.
5. *Apply* some short-term cost reduction tactics to delay downsizing, such as (a) reduced work week, (b) unpaid leave of absence, (c) early retirement incentives, (d) job sharing, (e) buyout incentives, (f) facility shutdown, (g) salary reduction, (g) minimize expense budget, (h) partially paid employee sabbaticals, and others (Cameron 1994).
6. *Offer* extensive post-layoff support to affected people, such as outplacement services, job search assistance, counseling, relocation assistance, and others.

12.4 Conclusions

In this chapter, we emphasized the importance of achieving OE for any product/service enterprise. OE is focused on doing things right (as related to internal work processes, customer problem solving, corporate knowledge management practices, speed of service delivery, and other supplemental service elements important to customers). It addresses issues related to cost, service quality, service availability, and work process reliability in order to maximize current corporate net income, and hence cash flow. For profit-oriented product/service enterprises, if there is no cash flow, there could be no activity and hence no corporate profitability. OE is centered on preserving the short-term performance of an enterprise.

As the marketplace becomes increasingly competitive on a global scale, STEM professionals and leaders should strive for OE on a continuous basis. Besides invoking the standard engineering management functions of planning, organizing, leading, and controlling to projects, teams, processes, and activities, they need to become versed in utilizing tools described in this chapter, such as Lean Six Sigma, web-based applications software, web services, and the low-cost and flexible computing capabilities offered by an emergent SOA-based IT utility. It would be wise for STEM professionals and leaders to keep lots of irons in the fire and go with whichever ones come to fruition.

Each of the tools described in this chapter has its rightful place in any enterprise, to be applied under the right circumstances. Reducing process speed is the primary drive of the Lean principle. Service quality is emphasized by the process-standardizing approach, by following the best practices established in the industries, and by practicing Six Sigma methodologies. The combination of Lean and Six Sigma will simplify work complexity. The application of value stream mapping helps to identify wastes, which are tasks that do not add value. OE is accomplished by having increased process speed, enhanced service quality, and minimized service costs. OE can be further enhanced by an increase in productivity, if web-based applications software is selectively employed on a pay-as-you-go basis.

Service contains a number of support elements, most of which are amenable to standardization, and the premise of Lean Six Sigma. The core service elements are exceptions; they cannot be readily standardized because of the differences in customers' needs. The use of web services and the emergent SOA-based computing model appears to offer an unprecedentedly high degree of operational flexibility, in addition to business computing agility and software reusability, which would enhance the optimization of these core service elements to achieve an improved level of service customization.

These tools should be seriously considered by STEM professionals and leaders when they strive to discover optimized approaches to deal with problems or opportunities in the future. They ought to keep themselves current with the future advancements reported in the emerging business computing domains.

For STEM professionals and leaders to contribute effectively to creating OE, they are advised to be: (1) knowledgeable of the relevant best practices in industry and familiar with new applications that generate new benefits for others; (2) capable of selecting, modifying, and implementing productivity/efficiency tools; (3) versed in conducting the basic management functions of planning, organizing, leading, and controlling as applied to projects, teams, programs, technologies, and other resources; and (4) supportive of the corporate drive to seek continuous improvement in all work processes, especially in those that have a direct impact on customers.

Governmental pressure is likely to force more health-care enterprises to become operationally efficient. Most enterprises will be compelled to practice many of these OE tools due to marketplace competition. Continuous improvement requires a commitment to learning. It is highly advisable for STEM professionals and leaders to constantly look out for opportunities to advance the level of OE of their enterprises.

QUESTIONS

1. How are URLs, domain names, and search engines defined? Use examples to explain the relationship between them. How can one make use of web pages to promote business?
2. What are the Internet, an intranet, and an extranet? How are they being used by numerous large and small companies today?
3. What are the standard markup languages used in the design of web pages?
4. What are some of the legal issues related to the Internet and web-based business transactions that remain unresolved at this time?
5. In implementing a computerized maintenance management system to reduce maintenance costs, what steps are taken?
6. What is data mining, and how significant is it in generating useful results to support management decision-making?
7. For the development of software products, the software configuration management (SCM) process is closely followed as a way to ensure performance and reliability while controlling costs. Explain what SCM can do and in what ways it is important that both developers and intended customers insist on SCM.
8. Although marketing and sales are not functions of engineering, they have a direct impact on product development and CRM. Which web-based applications are currently available to facilitate marketing and sales?
9. The business environment in the new millennium will continue to be fast paced, Internet enhanced, and globally oriented. Name a few factors that will affect the business successes of any companies in such a challenging environment.
10. The "Design for Lean Six Sigma (DFLSS)" is a methodology known to be particularly useful for designing new services that are in close alignment with customer and business needs. Explain the key phases the DFISS methodology goes through.
11. Services are known to have many wastes, which, if not removed, will increase costs and erode service quality, leading to customer dissatisfaction. Name a few of the typical wastes encountered in service offerings.
12. The Lean principle focuses on the improvement of process speed. It is thus particularly useful to service enterprises, which need to shorten customer response time. Explain the basic concepts involved in Lean to improve process speed.
13. There are two types of web services. The first type offers software applications that are accessible to human users. The second type provides software applications that can be accessed by other applications. Explain the basic requirements of building web services to create applications, which can be accessed by human users.
14. As SOA service vendors are likely to be consolidated over time, an IT utility will emerge. In that scenario, most businesses will "buy" computing services instead

of maintaining their own in-house computing data centers, much like how business, commercial, and residential customers buy electricity today. What are the potential concerns to service enterprises, which become dependent on the IT utility, insofar as operation and financial risks are concerned?

Appendix: "Service" Model

Lean Six Sigma may be usefully applied to service-related work processes by following the seven-step SERVICE model described in this section:

1. *Study customer value:* Select those tasks/processes and activities that are likely to invigorate customer satisfaction. Lovelock and Writz (2014) illustrate the service value package as consisting of a core benefit supported by eight supplemental service elements (see Figure 12.A1). For a service to be appreciated by customers, both the core and its supplemental elements should be fresh and well formulated, because all of them will affect the overall perception registered by the customers. This model fits well with different service value packages, although not all supplemental service elements are equally important to different core services. Some supplemental service elements engage the customers directly, thus having a more profound impact on influencing the customer's perception than others. A useful way to prioritize the target activities for applying Lean Six Sigma is then to look at the core and the supplemental elements of the service value packages offered by the enterprise.

   Processes that go into a service can also be classified into the types of highly customized, mass customized, and standardized. Among these three types, the best candidates for applying Lean Six Sigma are the standardized processes,

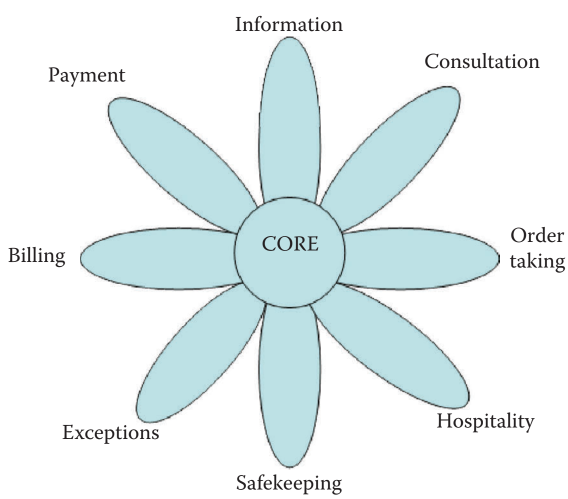

FIGURE 12.A1
Service elements.

such as payroll and benefit processing, credit card account services, and fast-food services, according to Biolos (2002).

2. *Evaluate these service elements* and map their relative values to customers. Take a cross-functional view to screen out activities that do not add value and to identify activities that cause processing delays (Martin and Osterling 2013).
3. *Refine the work flow diagrams* to preserve process data and materials for analysis.
4. *Validate and improve on cycle time*, and adopt the pull strategy to expand Lean Six Sigma activities. By way of promotion and corporate endorsement, company employees are inspired to voluntarily participate, so that the Lean Six Sigma projects are to be pulled through all units of the company. In order to encourage employee buy-in and acceptance, it is advisable for the service enterprise to start with a meaningful but self-contained project that does not require changes of other processes, and then to promote the resulting successes aggressively.
5. *Institutionalize the drive* for continuous improvement—applying the DMAIC process of Six Sigma to the target process/activities in order to upgrade quality and productivity.

   Define service defect and the ways to measure it. From the customer's standpoint, a service defect is a flaw in a process that results in a lower level of customer satisfaction, higher service turn-around time, or a lost customer.

   Consumers' Checkbook, an independent rating organization, uses the following metrics to rate banking services: (a) overall, (b) pleasantness of staff, (c) knowledge of staff, (d) speed of service, (e) reasonableness of fee policies, (f) convenience of hours, and (g) clarity of written communications (Lovelock and Wirtz 2014).
6. *Call out the complexities* hidden in the process and activities, using both value stream mapping and Six Sigma. Complexities are brought about by service differentiations. Standardizing the supplemental service elements may be useful to eliminate complexities. Since the core service elements are usually customized and thus highly differentiated, eliminating those supplemental service elements that do not contribute to profitability will help. The outcome of eliminating complexities will be the reduction of costs and wastes.
7. *Excel in delivering* a Six Sigma level of service quality at lean speed and low cost. Lean Six Sigma is an important productivity tool for various service operations. Some lessons learned in employing Lean Six Sigma may be found in (George 2010). Service professionals and leaders are advised to appreciate its strategic importance to service enterprises and implement the SERVICE model properly.

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13

Globalization

13.1 Introduction

Globalization is defined by the International Monetary Fund as the growing economic interdependence of countries worldwide through the increasing volume and variety of cross-border exchanges in goods, services, international capital flows, and technologies. As the boundaries between countries, industries, and market segments crumble, everyone is facing a plethora of competition.

Globalization is not a new phenomenon. International trade and commerce have a very long history. In recent years, the growth of the world economy and the migration of goods, services, capital, people, and technologies across borders have increased. The rapid expansion of the digital economy has also helped to accelerate the pace of globalization (Ritzer and Dean 2015; Rupp et al. 2014). Some American companies are expanding to reach new global markets and foreign resources. Instead of only a few countries handling the trade of most currencies and goods, now many more countries play a part. American companies are actively pursuing markets in Asia, Europe, Latin America, and other regions. Examples of such companies include Wal-Mart, Exxon-Mobile, General Electric, Bank of America, Ford, and IBM. Some foreign-owned companies have achieved more sales revenues outside their home countries than in their respective domestic markets (Gupta et al. 2008). Although the domestic automobile market in Japan continues to fluctuate, Toyota is expanding aggressively in the United States, Europe, and China. As reported by *Fortune Magazine* recently, Toyota has now surpassed Ford as the number-two automaker in the world, just slightly behind General Motors in global unit sales.

Globalization is recognized as one of six mega trends (Vielmetter and Sell 2014). The other five mega trends that will impact on business in the years to come are (1) environmental crisis, (2) the digital era, (3) technological innovations, (4) aging populations, and (5) mobility of self-centered professional workers.

In this chapter, we will explore various management issues related to globalization (Seitz and Hite 2012). Our emphasis will be steps that science, technology, engineering, and math (STEM) professionals and leaders may take to seize new opportunities offered by globalization.

13.2 Global Trends and Commerce

The world economy has become interdependent in recent decades. The worldwide integration of national economies—through the trade of goods, services, capital, and technologies—has become broad and deep. As a percentage of its gross national products (GNP), the United States has seen its trade (the sum of import and export values) increase steadily over the last several decades. Another indicator of global trade activities is the constant increase in the strategic alliances formed between multinational companies.

13.2.1 New Trends in Global Market

There is indeed a huge tectonic change in the global landscape. Several trends are generally noticeable among the global companies. Large corporations are steadily increasing their scale and scope. Mega-institutions have disproportionately high profits and market values, as they take advantage of the talents of their professionals and knowledge workers. The book value of these large companies is shrinking, as they compete with the knowledge and talents of their employees, instead of the physical assets on the ground. These large companies produce more profit per employees.

Also noticeable are several trends that affect the global business markets: (1) innovation (in products, services, and business models), (2) free flow of information, (3) expanded access to talent, (4) availability of cheap labor, (5) increase in low-cost competitors, and (6) reduction of trade barriers.

McKinsey Corporation conducted a survey among over 3600 business managers in Mach 2007, which identified a set of 14 global trends; these trends, listed in the order of their relative impact on business, are

1. Growing numbers of consumers in emerging economies (by 2025, China alone is projected to have 520 million upper-middle-class consumers; this is the market of the future)
2. Increasing availability of knowledge/ability to explore global opportunities
3. Increasingly global labor and talents markets
4. Shifting economic activities between and within regions
5. Development of technologies that empower consumers and communities
6. A faster pace of technological innovation
7. Increasing constraints on supply or usage of natural resources
8. An aged population in developed economies
9. Geopolitical instability
10. Increasing sophistication of the capital markets
11. Adoption of increasingly scientific management techniques
12. Shifting industry structure/emerging form of organization
13. Social backlash against corporate activity
14. Growth of public sector

Battelle, a company focused on technology development, commercialization, and product development with 7500 employees and an annual revenue of about $1 billion, identified 10 technology-centered trends for the next 20 years:

1. Genetic-based medical and health care
2. High-power energy packages

3. Green-integrated technologies to produce recyclable products and eliminate solid wastes
4. Omnipresent computing (big data, business analytics, and Watson-type artificial intelligence processing)
5. Nanomachines to enable localized drug delivery to attack cancer cells
6. Personalized public transportation
7. Designer foods and crops
8. Intelligent goods and appliances
9. Worldwide inexpensive and safe water
10. Super sense (with enhanced reality for hearing)

Global companies are expected to plan accordingly by initiating timely actions to seize new opportunities and minimize related risks.

13.2.2 Multinational Enterprises

Multinational enterprises (MNEs) are those that operate in more than one country. As of 2001, there were about 45,000 MNEs in the world. These enterprises play important roles in the global economy. They hold 90% of all technology and product patents worldwide, and conduct 70% of world trade (30% of which is intracompany). These enterprises also pursue diversified businesses, such as mining; refining and distributing oil, gasoline, diesel, and jet fuel; building energy plants; extracting minerals; making and selling automobiles, airplanes, communication satellites, computers, home electronics, chemicals, medicines, and biotechnology products; harvesting wood and making paper; and growing crops and processing and distributing food products. Furthermore, these enterprises induce governments to form treaties and trading blocks among the European Union, the North American Free Trade Agreement (NAFTA), the World Trade Organization (WTO), the Multilateral Agreement on Investment, and the Uruguay round of the General Agreement on Tariffs and Trade (GATT). These treaties tend to provide great power and authority for MNEs to pursue globalization, thus increasingly undercutting the authority and power of national governments and local communities.

The 500 largest MNEs are responsible for 80% of all foreign direct investments (FDIs). Of these MNEs, 443 are located in only three regions: the United States, the European Union, and Japan. (A detailed distribution of these major MNEs is presented in Figure 13.1.)

Available trade data illustrate the extent of dominance by the MNEs operating in the triad regions (e.g., NAFTA, European Union, and Asia). Most of the export trades recorded have been within the three regions. The total exports from these three regions to countries outside the regions was only a minor percentage of the total. As a result, some researchers charge that the operations of these MNEs are de facto regional, not global (Rugman 2012).

If we take a longer-term view, we cannot afford to ignore the forecast made by the World Bank (1992). According to this forecast, by 2020 the largest economies in the world are projected to be China, the United States, Japan, India, and Indonesia. According to an International Monetary Fund (IMF) World Economic Outlook (WEO) report of October 2015, China is already the largest global economy based on purchasing power parity (PPP) (see Table 13.1).

Economic growth rates in emerging markets for the future are predicted to be 3 to 10 times that of the United States. About 50% of worldwide gross domestic product (GDP)

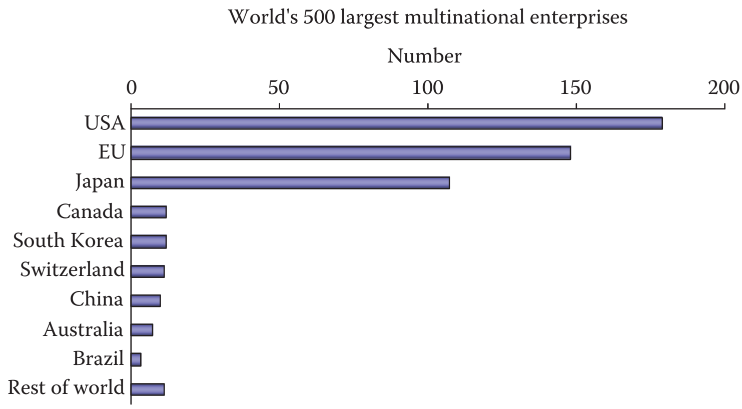

FIGURE 13.1
Current concentration of major MNES.

will be generated in emerging markets. Consequently, we should expect that the situation just described (i.e., the MNEs having only regional operations for now and the home bases of the top 500 largest MNEs being concentrated in the triad regions) will surely change in the years to come. The roles played by the emerging countries in Asia, such as China, India, and Indonesia, could become substantial indeed. The extent of trade and commerce globalization is expected to further increase.

Goldman Sachs, an investment firm based in New York, studied the GDP of both the G6 (composed of the United States, Japan, Germany, France, Britain, and Italy) and BRICS nations (BRICS is an abbreviation for Brazil, Russia, India, China, and South Africa). Canada is normally part of the G7 nations, but is excluded in this study because its GDP is only about 3% of the G7 total. Goldman Sachs predicts that by 2037, the total GDP of BRICS will match that of G6. Should this prediction hold true, it would mean that the next phase of globalization would be manifested in the expansion of global economic activities from being centered on the G6 nations at the present time to encompass the BRICS within the next 30-plus years, and that high economic growth rates would be found primarily in BRICS nations.

This type of forecast is, of course, valid only in the absence of any disruptive events, such as wars, global economic recessions, or natural disasters. Nevertheless, it does foretell

TABLE 13.1

New Ranking of Nations Based on Gross National Products (PPP)

#	Ranking	GDP (Billions)
1	China	19,510
2	USA	17,968
3	India	8,027
4	Japan	4,842
5	Germany	3,842
6	Russia	3,474
7	Brazil	3,208
8	Indonesia	2,839
9	United Kingdom	2,660
10	France	2,647

Source: IMF World Economic Outlook (WEO), October 2015.

the emergence of some developing economies and the increased degree of cross-border exchanges in the years ahead.

13.2.3 Ownership of Global Companies

The five major stakeholders of any company are customers, employees, suppliers, investors, and the communities in which the company operates.

A large number of global companies manufacture products/services designed to reach global customers, employ workers from different countries, source materials and components from suppliers in global markets, interact with local communities at global locations, and have global investors. In recent years, countless countries have been setting up stock exchanges and security markets to attract foreign or domestic investments. Nowadays, it is easy for an investor to become a shareholder of any global company that is traded in one of many public stock exchanges.

As illustrated in Figure 13.2, the ownership of Nestlé, a well-known MNE, is quite global indeed. No single Nestlé shareholder owns more than 3% of the company stocks. This trend of global ownership is expected to continue as the capital markets become more accessible to investors residing in various countries. Over time, companies will diligently apply innovative global marketing strategies to sell products/services to global customers, in order to create value for a global ownership.

Example 13.1

What are some practical reasons for a company to ever want to expand into the world of international business?

Answer 13.1

The reasons for a company to want to expand into the global markets are plentiful. The following are the primary few:

1. *Desire to expand markets (finding new customers)*: For companies whose products have been selling in a saturated domestic market at home, expanding into global markets represents an attractive opportunity to find new customers.

   Theodore Levitt (*Harvard Business Review* editor) proposes the idea that the characteristics of some products are converging, making them more and more

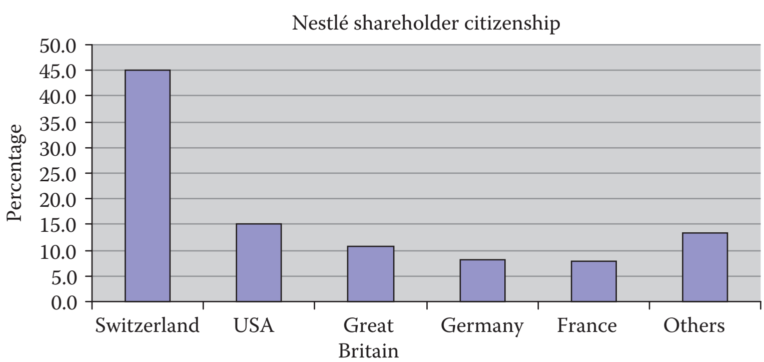

FIGURE 13.2
Ownership of Nestlé.

universal, thus allowing companies to market them to the global marketplace. Companies may be able to derive advantages based on the global economies of scale. However, in order to do well, companies will need to understand the local customers, business practices, and cultures of global customers.

2. *Search for natural resources*: Companies pursue foreign investments to avail themselves of resources that may otherwise not be readily available. U.S. investments in Saudi Arabia and various U.S. offshore gas exploration projects are the prime examples.
3. *Proximity to customers*: Companies expand into the global marketplace to be closer to their customers, for the sole purpose of understanding and serving them better, faster, and cheaper. Some products require customization in order to enrich the value offered to the customer. Customer satisfaction will increasingly become a key competitive focus. Companies that are in a position to understand their customers more thoroughly and are able to customize their products better, will have a significant advantage in the marketplace.
4. *Labor savings*: Today, certain developing countries offer skilled labor at a fraction of the cost needed to hire similar workers in the home countries of numerous major companies. Mexico is a prime example. Many U.S. companies have set up manufacturing shops in Mexico. The products made there are shipped back to the United States for distribution and marketing. Several other countries, such as China, India, the Philippines, and Thailand, are also candidates for companies to realize labor savings in certain types of products or services.
5. *Access to innovative talents*: A large number of U.S. companies are known to have set up research and development (R&D) centers in China, India, and Russia to engage talented professionals for various creative ventures.

Example 13.2

When companies attempt to pursue global markets, which common entry strategies are deployed?

Answer 13.2

There are several common entry strategies into global markets. In general, companies are well advised to first study the relative attractiveness of the target market (e.g., specific segments in different countries) by considering factors such as profitability, market size, and market growth. In addition, companies need to assess the degree of acceptance of their products in these targeted marketplaces (e.g., brand name, competitive position, and market access). Once the most favorable product–market-segment pairs are selected, companies may pursue these global markets by (1) exporting, (2) licensing or contracting manufacturing, (3) forming joint ventures with local partners, (4) creating a foreign branch of the company, and/or (5) establishing a foreign subsidiary of the company.

13.3 United Nations Statistics and Goals

Statistics published by the World Trade Organization (WTO) indicate that world trade, defined as the total value of export, has increased about 400% over the last 30 years at a compound growth rate of 5.5% per year.

It is well known that countries open to global trade grow twice as fast as those that remain relatively closed to trade. At least two African nations, Nigeria and Tanzania, have chosen to rely on protectionism, foreign aid, and inefficient public policy. Today, they remain at the 1960s economic development levels of Malaysia, Thailand, and Indonesia. In recent years, Latin America has started to embrace market liberalization. It has abandoned its old policies of a dominant state presence in the economy, import substitution, and domestic industry protection. The results of these changes are encouraging, and more countries are expected to jump on the globalization bandwagon.

According to the World Bank (2001), the world output is projected to increase 33% from $30 trillion in 2001 to $40 trillion in 2010. The disposable income in regions such as China, India, Southeast Asia, and Latin America will double over the same period. About 300 million people (roughly the size of the population of the United States) will join the thriving worldwide middle class in the next 10 years (Kochhar 2015).

On the other hand, World Bank statistics also show that, from 1990 to 2000, only about 800 million people moved out of absolute poverty, which is defined as having less than one U.S. dollar per day of income. As of 2001, 50% of the world population lived on less than $2 per day. Eighty percent of the global population lives on less than 20% of the global income.

The United Nations (UN) has declared that one of its goals is to decrease the number of people in absolute poverty by 50% by 2015. Globalization is regarded as a key process in achieving this very meaningful goal (Lamberton 2002).

13.4 Great Philosophical Debate about Globalization

Not everyone favors globalization. It creates winners and losers. Generally speaking, government leaders of both large and small countries are in favor of globalization because of its heightened opportunities for FDI, transfer of technology and best practices, and trade benefits. Business leaders are strong advocates of globalization for many reasons, including the following: (1) greater flow of trade and investments stimulates economic growth; (2) rising outputs bring about employment and income, which means higher living standards for consumers; (3) higher living standards facilitate a greater social willingness to devote resources to the environment, education, health care, and other social goals; (4) global competition keeps domestic business competitive and innovative, which leads to higher quality output and productivity; (5) rapidly developing economies tend to generate a new middle class that is the bulwark of support for personal liberty and economic freedom.

Opponents of all stripes and creeds blame globalization for many of the world's ills (Stiglitz 2003). They are primarily from three major groups: labor union members, human rights activists, and environmentalists.

The labor union wants to protect local jobs in industrialized countries, as globalization will likely induce MNEs to transfer manufacturing and other high-paying jobs to emerging economy regions in search of cost-competitiveness. They also raise the issues of child labor and forced labor in poor countries, citing past incidents of exploitation by MNEs.

The human rights groups claim that local economic growth induced by globalization in some emerging countries may allow their respective dictatorships to stay in power longer, thus indirectly supporting continued suppression of the people. Globalization would become an inadvertent coalition partner in crime against humanity (Nault and England 2011).

The environmentalists believe that, by relocating their manufacturing operations to developing countries with lower environmental control standards, the MNEs are essentially exporting pollution and other environmentally unacceptable practices to the poor countries, thus causing irreversible damages (Shenkar et al. 2014).

These three groups are united in their opposition to globalization. Their reasoning is further summarized as follows:

1. Globalization is a conspiracy of big companies exploiting less-developed countries. It concentrates market power in the hands of a few large corporations, allowing them to trample over smaller commercial rivals and flourish at the expense of small companies and consumers. Globalization is akin to companies without rules.
2. Globalization promotes the suppression of human rights in developing countries.
3. Globalization destroys the environment.
4. Globalization spreads terrorism, narcotics, disease, and money laundering (Condon 2002; Kugler and Frost 2002; Horowitz 2003).
5. Globalization lowers labor standards and turns emerging economy nations' workers into "slaves."
6. Information technology (IT) is a "tool for evil" in globalization.
7. Globalization takes away jobs from the United States.
8. Globalization undermines cultural diversity.
9. Globalization widens the gap between the rich and the poor.

Some of the arguments in opposition to the antiglobalization views include

1. *Representation*: Numerous antiglobalization demands reflect the values of young, middle-class U.S. and EU consumers. They may not be the true representative voice for the emerging economy countries they claim to speak for.
2. *Dominance*: Globalization does not mean the triumph of giant companies over small ones. A case in point is Nokia versus Motorola. Nokia is small in size and dynamic in marketing strategy; this attests to the fact that corporate size is not a requirement for global success. Globalization does shift the balance of advantages from local incumbents (big or small) to foreign challengers. Protection barriers such as the high cost of capital and the difficulty of acquiring new technologies are gradually removed over time.
3. *Environment*: It is partially correct that globalization may indeed affect the environmental conditions in some emerging economy countries. Their competition to attract foreign investment could accelerate the importation of production plants that generate carbon dioxide, toxic wastes, and other environmentally unacceptable discharges.

   It is true that any pollution discharged into the ambient air by a production plant is bad for the environment. In the United States, various environmental regulations for reducing harmful emissions were enacted only after many tough struggles between big business and government. The key issue is how to balance the value created by greenness with that produced by wealth and economic progress. While the United States can afford to go green at present, its current environmental standards may not be appropriate to impose on other countries that are in situations comparable to the United States in the 1960s.

Thus, the acceptable degree of greenness for a given country is not to be decided by rich countries' environmentalists. For India and other countries, wealth generation may be more pressing in the short run than environmental greenness. This is why currently the governments of various emerging economy countries welcome globalization and do not share the views of environmentalists in developed countries.

However, some local governments and global companies have different views. Levi Strauss established ethical manufacturing standards for its overseas operations. Home Depot adopted an ecofriendly lumber supply program. Starbucks buys coffee from farmers who preserve forests.

4. *Labor standards*: The claim that globalization diminishes labor standards is a questionable one. The key issues involved are wages, work conditions, and child labor.

   Most FDI is value driven and does not primarily chase after low wages. For example, the United States has a positive FDI, meaning that the total amount of foreign investment in the United States is larger than the U.S. investment abroad. Clearly, this surplus FDI is not driving down U.S. labor standards.

   The governments of emerging economy countries oppose the imposition of the current U.S. and EU labor standards on their regions, as doing so will cause them to lose the wage advantages they currently enjoy. Imposing an external wage standard that is not locally sustainable can be harmful, as evidenced in Germany. After reunification, West Germany imposed its high wage standards on East Germany. The result was an economic disaster: there was zero growth and high unemployment in the East. The governments of developing countries argue that the Asian "Tigers" (e.g., Taiwan, South Korea, Hong Kong, and Singapore) have convincingly shown the road to prosperity for developing economies. Each of these countries started out with low wages and cheap exports and then allowed wages and income to rise gradually in concert with the increased value of products/services they produce and the improvement in their workers' skills. Local wages must be sustainable in local economies. As expected, all emerging economy countries insist on speaking for themselves and want more investment, freer trade, and better enforcement of local laws, not the imposition of foreign wage standards.

   In general, global companies do provide higher wages to their workers than their local rivals. Some global companies have started paying attention to workplace conditions as well. Gap and Nike are said to have adopted codes of conduct for their overseas plants.

   Child labor is commonly accepted on American farms today and was legal during the long period when the United States was a developing country. Imposing twenty-first-century labor standards on today's emerging economy countries thus runs the risk of appearing hypocritical. For many families in emerging economy countries, child labor may be a major source of income, just as it is on American farms today and was for others many years ago.

5. *Human rights*: The argument that globalization suppresses human rights is also a questionable one. According to Maslow's hierarchy of needs, once a person's physiological needs (clothing, shelter, transportation, and other subsistence needs) are met, the next higher levels of needs (social acceptance, peer recognition, and

self-actualization) become activated in search of continued personal satisfaction. Accordingly, the local population will most likely seek more freedom of speech, rights of assembly, and respect for human rights over time, but only after their basic subsistence needs are met. An example is Taiwan, which transformed itself peacefully from a dictatorship to a democracy through its rapid advancement of global trade and economy.

6. *Side effects*: Globalization promotes free trade and the exchange of goods, services, information, money, and technologies across national borders. Indeed, there are no effective solutions for minimizing the detrimental side effects of increased flows of terrorism, narcotics, disease, and money laundering, unless the governments involved are committed to forcefully combat them. In addition, an aggressive implementation of some of the following programs may help (1) enhance educational training for the poor (postsecondary, vocational); (2) make social services more widely available; (3) adopt policies to strengthen the productive capabilities of all, including the low-income groups; and (4) set up safety nets (e.g., social security and unemployment insurance) for those who are in need.

It is true that what one believes depends on where one stands. Winners and losers have different views on globalization. In the United States, the steel industry is in deep trouble, due mainly to cheap imports. The U.S. textile and farm industries need governmental subsidies to survive. On the other hand, U.S. high-technology industries (e.g., electronics, computers, airplanes, appliances, consumer goods, telecommunications equipment, and banking services) are benefiting tremendously from an open global market.

Globalization is an inevitable and unstoppable trend that unfortunately causes dislocations. A prudent approach should be to go forward with globalization while initiating steps to minimize its detrimental side effects. Examples of such steps include asking MNEs to support education and job-skills retraining in emerging economy countries, encouraging MNEs to adopt responsible environmental and labor practices when producing products/services in host countries, and promoting democracy and respect for human rights.

13.5 Impact of Catastrophic Events on Globalization

In recent years, several major events have had a profound impact on the world economy, political stability, and peace. These events include the terrorist attack on the Twin Towers of the World Trade Center in New York City on September 11, 2001; the Iraq War in 2003; the severe acute respiratory syndrome (SARS) outbreak in South China in 2003; Ebola; ISIS uprising in the Middle East; Israel—Palestinian conflicts; Ukraine unrest; U.S. subprime conflicts; and the great recession (2008–2009). The immediate consequences of each of these events have been an increase in the cost of doing international business and changes in business relationships between the United States and other countries. A number of projected factors may exert a cooling effect on globalization:

1. Since the war against terrorism may be protracted, insurance premiums may be raised because of heightened security concerns.

2. Increasing security risks reduce the willingness of business people to travel internationally and may lead to a reduction in team performance, collaboration, information sharing, and knowledge management.
3. A higher return may be demanded to compensate for increased investment risks.
4. Heightened border inspections may slow cargo movements and force companies to stock more inventories (such as spare parts).
5. Tighter U.S. immigration policies could curtail the inflow of skilled and blue-collar workers (e.g., from Mexico and Canada to the United States).
6. Time horizons for international projects may be shortened when companies make new FDI.
7. The availability of global equities may drop because a smaller number of investors are willing to take the added risks involved. FDI to specific countries regarded as posing a high risk (e.g., India, Pakistan, the Philippines, parts of South America and Southeast Asia, most of the Arab world, and Russia) may be cut.
8. Because of disagreements with U.S. foreign policy, some businesspeople from Third World countries may become reluctant to make deals with American businesses.
9. High unemployment rates created by the great recession from 2008 to 2009 discouraged foreign, talented professionals to seek employment in the United States.

There are countless specific examples of the rising costs and risks of doing international business. U.S. expatriates are leaving Indonesia because of the radical Islamic unrest against U.S. and British interests there. Cargo-laden trucks are taking seven hours to cross the Laredo, Texas, border crossing, compared with only two hours before the September 11, 2001, terrorist attacks. Delphi Automotive Systems, which operates 56 plants in Mexico, scheduled 200 trucks per day to bring products into the United States before the terrorist attacks. Now, the company ships parts in smaller lots more frequently so that it can redirect shipments to planes, boats, or helicopters if the transportation situation so requires.

It may take several years for these effects to dissipate and for the world economy to resume a normal growth pattern.

13.6 New Opportunities Offered by Globalization

Globalization offers some unique opportunities for companies to explore. According to Gupta and Govindarajan (2001), there are five globalization-specific opportunities available, namely, (1) adapt to local market differences, (2) exploit economies of global scale, (3) exploit economies of global scope, (4) tap optimal locations for activities and resources, and (5) maximize knowledge transfer across locations.

13.6.1 Adapting to Local Market Differences

Among local markets, there are major differences in language, culture, income levels, customer preferences, distribution systems, business practices, and marketing environment. Companies need to adapt their products, services, and processes accordingly.

Business Week is known to have North American, Asian, and EU editions. Baskin Robbins introduced ice cream flavored with green tea in Japan. Coke markets Asian tea (sokenbicha), English tea (kochakaden), coffee drinks not offered by local competitors, and fermented milk drinks in Japan.

Anheuser-Busch Inc. successfully marketed its premium and regular beer products in aluminum cans in diverse countries except China. After a careful market study, the company adapted to local conditions by switching to glass bottles and marketing its premium-grade beer in large bottles to restaurants and regular-grade beer in small bottles to average consumers who buy from their local supermarkets. Budweiser scored a huge sales success in China, because this marketing strategy added value to all three parties involved. Chinese customers are known to like to show off by ordering premium beer in large bottles when inviting friends to eat in restaurants, typically ordering one big bottle for each friend at the table. When they buy beer to consume at home, they want to save money, as no one else is around for them to impress. Furthermore, using glass bottles that could be readily sourced locally and recycled pleased the Chinese government. These practices increased the local labor involved in bottling the contents of the products and eliminated solid-waste disposal problems brought into being by aluminum cans. For the company, this strategy whittled down the beer product cost by doing away with the need to import expensive aluminum cans from the home country.

Whirlpool markets the White Magic washing machine. The company runs a global factory network that makes basic models with 70% common parts; the remaining parts are readily modifiable to suit local needs. For the Indian market, it conceived a TV-based advertisement program to associate Indian housewives' belief that white means hygiene and purity with Whirlpool washing machines designed to be capable specifically of washing white fabrics in local water. The company offered incentives for local retailers to stock washing machines and hired contractors conversant in 18 local languages to deliver products and collect cash payments. Annual sales of Whirlpool washing machines went up from $110 million in 1996 to $200 million in 2001—an impressive 80% gain.

Kodak has had tough competition in analog film sales and photo processing services from Fuji in Japan, Agfa in Germany, and other global players. In China, Kodak markets its franchise business, the chain of Kodak Express photo supply and development shops, to small entrepreneurs by (1) supporting the franchisee by offering Kodak equipment as collateral to secure local bank loans, and (2) supplying monthly training services to transfer know-how. Kodak was able to establish about 10,000 Kodak Express shops in China by the end of 2001. Its Chinese market share increased from 30% in 1995 to 60% in 2001. However, Kodak has been in decline since then. So are some other well-known brands, such as Sears, Radio Shack, and J.C. Penney.

Not adapting to local conditions could lead to business failure. Walsin-CarTech, a joint venture of CarTech with Walsin-Lihwa in Taiwan, planned to build a steel mill in South Taiwan to produce 200,000 tons per year of stainless steel and carbon bar, rod, and wire products for the world markets. Unexpectedly, the local farmers around the intended plant site delayed the installation of electric power lines until they were financially compensated. The Taiwan government also complicated the plant's permitting process. Meanwhile, competitors added their production capacity for stainless steel. The plant needed more investment capital to build than originally expected. The two-year delay in the plant start-up caused the joint venture to miss the window of opportunity. Subsequently, CarTech abandoned the joint venture in 1998 and moved on to form a steel joint venture in India.

Adapting to local markets will likely allow companies to increase their market share, augment their gross margin due to enhanced value to customers, and neutralize local competition. However, the cost increase associated with local adaptation must be commensurate with the value added to customers, inducing them to pay for the higher price charged. TGI Friday's incorporated many local dishes (e.g., kimchi) into its menu when it entered the Korean market. This strategy backfired because Korean customers wanted to visit TGI Friday's to taste American, not Korean, food.

The degree of local adaptation may shift over time as the result of the global media, international travel variables, and a steady reduction in income disparity. Companies must constantly adjust their local adaptation strategies.

13.6.2 Economies of Global Scale

Companies may realize economies of global scale by taking a number of steps, such as (1) spreading fixed costs—R&D, operations, and advertising; (2) reducing capital and operating costs per unit when production capacity is increased; (3) pooling purchase power—volumetric discounts and lower unit transactions costs by sourcing from a few large suppliers; and (4) creating a critical mass of talent—centers of excellence for specific products and technologies.

Autobytel refined a global baseline architecture that consisted of software modules that can be snapped together in various combinations, depending on the local needs. There are hooks for adding customer software when required. New features invented for a specific country may be incorporated back into the baseline if it seems likely that they will be used elsewhere.

There are a number of counterbalancing factors to consider. Too much centralization in product manufacturing can mandate higher costs of distribution. Concentrated production can also isolate the company from the targeted marketplace. Procurement from a few suppliers generates dependency and constraint, insofar as supply disruptions related to labor unrest, access to world-class technologies, and utilization of existing competencies are concerned.

13.6.3 Economies of Global Scope

Globalization allows products and services that do not require local adaptation to be marketed to multiple regions and countries. Companies can benefit by

1. Providing coordinated marketing approaches for standard products (e.g., PCs, software products, and ketchup used in McDonald's) to achieve greater consistency in quality, faster or smoother coordination, and lower unit transaction costs.
2. Leveraging market power and customer-specific insights, as a global supplier understands a global customer's value chain better and hence is better prepared to serve. For example, FedEx, as a multilocation logistics service provider, better understands the needs of Laura Ashley, a multilocation global customer.
3. Specifying the same hardware platform design for all global locations. GM uses Unigraphics as its common computer-aided design and manufacturing tool and design environment, making it easy for global engineers to collaborate 24 hours a day.

In 2003, IBM entered an eight-year contract worth $1.2 billion to take over the North American and European information technology operations of the French tire company Michelin.

However, there is a challenge facing the management of centrally coordinated marketing programs: how should businesses reconcile the tension between the needs of headquarters and those of the regional units in the actual delivery of products and services?

13.6.4 Location-Based Optimization

This is another globalization-specific opportunity for companies to develop new businesses. Certainly, the intercountry differences in location-based cost structure and services must be considered. By optimally selecting the location for each activity in the value chain (e.g., R&D, procurement, component manufacturing, product assembly, marketing, sales, distribution, and service), global companies can secure advantages in several areas.

1. *Performance enhancement*: To build and sustain world-class excellence conferred by talents, speed of learning, and the quality of external and internal coordination, Fiat chose Brazil, not Italy, as the place to design and launch its "World Car," the Palio. Microsoft established a corporate research laboratory in Cambridge, the United Kingdom, rather than in the United States.
2. *Cost reduction*: Cost is, of course, a major concern to any company. Cost considerations relate to factors such as local manpower and other resources, transportation and logistics, government incentives, and local tax structures. For example, Texas Instruments set up a software development unit in India, and Nike sources the manufacture of athletic shoes from Asian countries (i.e., China, Vietnam, Indonesia, and others).
3. *Risk reduction*: Beside economic and political risks, there are also currency risks associated with devaluation. A company might need to spread the manufacturing operations across a few locations to minimize such risks.

For instance, Texas Instruments has been designing integrated circuits in India since 1986, Sun Microsystems has hired Russian scientists for software and microprocessor research, and CrossComm Corp has its communications software written by Poles at the University of Gdansk.

To capture location-based opportunities, companies need to have the right management skills with the flexibility and the ability to foster coordination.

Ford relocated some manufacturing operations to Mexico to become more selective in hiring, to achieve a reduction in turnover, and to realize better productivity by training. Ford was able to achieve lower wage rates as well as higher productivity than it would have been able to do in the United States.

Location-specific conditions do evolve over time. Companies must be flexible in shifting production should the location-based conditions no longer justify a continuation of production at a given site.

Coordination is of critical importance for companies to maximize the value generated by location-based opportunities. Texas Instruments conceived the product concept of its TCM9055 (high-speed telecommunications chip) in collaboration with engineers in Sweden. It developed the product in France with the use of software tools advanced in Houston, manufactured the product in Japan and Dallas, and tested the product in Taiwan.

13.6.5 Knowledge Transfer across Locations

The global company may add value by actively transferring knowledge across locations. Knowledge about product or process innovations and about risk-management options are of particular value.

1. *Product and service innovations*: Sharing new ideas among subsidiaries eliminates the "reinvention of the wheel" and speeds up product and process innovation.

   Procter & Gamble used ideas conceived at different centers to develop Liquid Tide in 1980: they built on technologies developed in Cincinnati (resulting in a new ingredient to help suspend dirt in wash water), Japan (cleaning agents), and Brussels (ingredients that fight the mineral salts present in hard water). Procter & Gamble applied an efficient stocklist-based distribution system from India to Indonesia and China and thus significantly minimized its cost of innovation.

   In 1997, ABB, a $23 billion industrial product company headquartered in Zurich, Switzerland, shifted 1000-plus manufacturing jobs from Western Europe to emerging economies over a five-year period for the purposes of increasing efficiency, exploiting lower wages, and becoming more responsive to customers in growth markets. ABB set up a system that propels local ideas for new products and projects around the world in just three weeks. On the basis of keywords contained in the proposal, principal global players comment and sign off within an allocated period; this minimizes the time from idea to approval.
2. *Reduced risks of competitive preemption*: By rapidly transferring new innovations to all global locations, the global company can lessen the danger of losing ideas to competitors for replication in other markets.

   Generally speaking, there are two types of knowledge that are important to a company. *Codified knowledge* is typically embodied in chemical formulas and engineering blueprints and is documented in operations manuals. Such knowledge is readily transferable. On the other hand, the *tacit knowledge* embedded in people's minds, in behavior patterns, and in the skills of individuals or teams may be difficult to transfer. Examples of such tacit knowledge include the vision of a road map of new technologies or competency in managing global customer accounts. Managers in global companies need to find effective ways to transfer tacit knowledge across subsidiaries.

   It is a natural tendency for people to want to preserve specific competencies (e.g., manufacturing superiority) for survival and competitive reasons. Global companies need to systematically recognize unique know-how that is worth transferring and encourage knowledge sharing across locations. All subsidiaries must also be encouraged to learn from peer units instead of being handicapped by the "not-invented-here" syndrome that some locations develop.

   Global companies are blessed with location-based, value-addition opportunities not readily available to companies that are domestically focused. Global leadership is needed to take advantage of these unique opportunities to create competitive advantages.

13.7 Preparation for Globalization

Pursuing globalization successfully requires that global companies understand the success factors gleaned from the experiences of others and that they are properly prepared. Preparation addresses the issues associated with management styles, globalization pathways, international perspectives, and personal readiness.

13.7.1 Success Factors for Globalization

In order to attain long-term profitability, global companies must (a) build customer relationships supported by superior, worldwide, and uniform service; (b) possess wide and deep knowledge about customers; (c) have strong and easily recognizable brands; (d) hire and retain talented people; and (e) organize global virtual teams to effectually implement global strategies.

Other key traits of companies that have successfully entered the global market include:

1. Home market strength, which provides a solid revenue basis for global expansion
2. A global business model that is easily replicated and scaled up to multiple markets
3. A powerful vision that motivates employees and communicates core values
4. Strong leaders who can articulate and carry the message globally

General Electric (GE) has been recognized as the master of globalization. It has moved a large number of plants to countries with lower labor cost. Specifically, GE locates and relocates manufacturing plants to locations where the GE quality standards can be met at the lowest cost. GE pursues the business tenet of "continuous mobility." As the emerging economies continuously improve their production skills and standards, GE relocates plants from one location to another to keep costs under control. General Electric Medical Systems, a division of GE, is known to have moved production plants from Paris to Budapest, from Milwaukee to Mexico City, and from Japan to Shanghai and Bangalore. According to Jack Welch, "Ideally, every plant you own would be on a barge." In Figure 13.3, quality standards are plotted against countries. The *x*-axis is also indicative of the relative cost for achieving

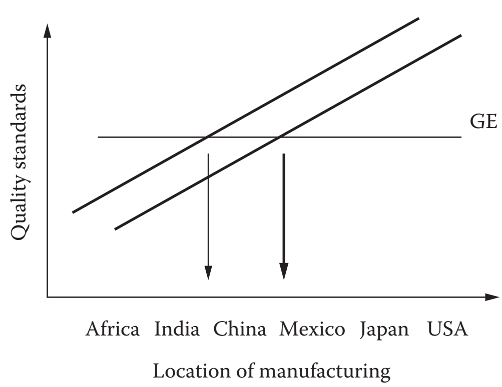

FIGURE 13.3
Continuous mobility.

a specific quality standard. It is generally expected that outputs of higher quality demand larger efforts and incur higher costs. Some developing countries are unable to produce quality beyond a certain level due to limitations in technology and skills. However, as the developing countries steadily upgrade their engineering and production skills, the quality–cost curve shifts to the left and moves from I to II. Most global companies will want to maintain high-quality standards for their products, while keeping costs competitive. For example, if GE operates at Point A at a given time, then it is only logical that GE seeks to operate at Point B, whenever it is feasible to do so, in order to reduce its cost base. Thus, moving its production plants periodically to lower-cost countries, while maintaining predetermined quality standards, is the basis of GE's "continuous mobility" strategy.

13.7.2 Global Virtual Team

To achieve global success, global virtual teams must function well, as the pace of change has increasingly forced global organizations to be more outward looking, market oriented, customer focused, and knowledge driven (Lipnack and Stamps 2000). Global virtual teams would typically be composed of members who are geographically dispersed, each with specific technical or business competencies, cultural and language backgrounds, working habits, and variable comfort levels with technology accessibility and utilization. Global teams may be ineffective because of cultural values, cultural and language differences, and other factors, such as the leader's approach, lack of organizational support, or individual rewards overshadowing the team's success (Zofi 2011; Fisher and Fisher 2011).

The cultural barriers just mentioned could come from (1) function—due to differences in reasoning styles, reactions, and getting motivated by people in various professions, such as engineers and marketing personnel; (2) organization—due to different value perceptions and behaviors; (3) nationality—due to different styles of human interaction because of national origin (e.g., in the United States the emphasis is on the individual, whereas in East Asia the emphasis is on the group and on reaching a consensus). Cultural issues need to be overcome. Metrics should also be set for goals and performance, and these should be focused on deliverables so that all team members fully understand their respective accountabilities. Managers also should convince all team members of the value of change made possible by the team activities.

Selecting the right team members is a crucial first step for the leader of any global virtual team. Preference should be given to people who can act on their own when needed. One model of membership selection is to find regional alliance partners who have the necessary core competencies to execute a global, centralized strategy. The best kind of alliance partners are those who think ahead, demonstrate commitment with investment, understand the company's requirements, share the common vision, and operate on behalf of the company.

When building global virtual teams, leaders need to pay attention to factors known to have a direct impact on team success. These factors include clearly articulating common goals, being aware of overlapping competencies and skills, acknowledging each other's contributions and needs, formulating clear procedures and ground rules for working together, and establishing common rules and technologies for sharing information and data.

In order to operate global virtual teams effectively, proactive attention and preventive maintenance are needed. Members will need to be trained properly. A constant monitoring of the team progress is advisable. Roles and responsibilities must be clearly communicated and emphasized. To get team feedback, frequent communication is to be encouraged.

Communication is the key to keeping teams together and on track. Poor communication can bring forth stumbling blocks affecting team success. Some of these stumbling blocks are (1) commitment of team members may be misdirected from global activities to local priorities (the "out-of-sight, out-of-mind" syndrome); (2) trust between global team members may not be strong enough; (3) time-zone differences, resulting in work-time overlaps, can discourage frequent communications; (4) language barriers, as English is not universally spoken, can make verbal and written communication in other countries uneasy and time-consuming for some; (5) culture differences produce different work habits and value perceptions, which can cause communication to be less free and open. Team leaders need to proactively schedule conference calls, in addition to e-mail, and have quarterly face-to-face meetings if budgets and schedules allow.

Example 13.3

Global teams are often deployed to handle important tasks, such as devising specific implementation plans, proposing market entry strategies, and designing global products.

How do you make global teams efficacious?

Answer 13.3

The following generalized steps could help make a global team efficacious in achieving its intended objectives:

1. Appoint a team leader who is well recognized for leadership quality, interpersonal skills, and managerial capabilities. Above all, the team leader must secure the strong support of the company's top management. The president or another suitable top executive of the company should announce the appointment of the team leader to demonstrate company commitment.
2. Specify the team's objectives, including standards to measure progress and the expected outcomes. The potential impact of the team efforts on the company's profitability is clearly understood.
3. Define the qualifications of the team members on the basis of the expertise and level of experience needed to achieve the team objectives.
4. Solicit suggestions from various regional management centers and receive assurance that all required local support (time off, secretarial work, analysis, use of local facilities and engineering, marketing, and other resources) will be offered to team members.
5. Interview specific candidates and select the team members with the concurrence of local management. Team members with different skills and expertise may be needed as the team progresses through various stages, resulting in a constant flow of people moving into and out of the team. By organizing the team properly, the team leader ensures that a good working atmosphere prevails at all times.
6. Compile a roster of corporate talents (who is specialized in doing what, for how long, with what accomplishments, etc.), with the support of local management. This roster should be constantly maintained and could be used by all team members.
7. Make sure that all members receive proper teamwork training regarding (1) working in teams; (2) communications, including the use of associated equipment and tools; (3) problem solving; (4) available support functions and resources that can be tapped, and (5) group goals and expectations.

8. Establish operational guidelines for fostering communications between team members (e.g., the use of intranet, videoconferencing).
9. Enhance personal interactions and cooperation, and build trust and confidence among team members by inviting all to be physically present at the first team meeting.
10. Conduct team meetings to focus on achieving the team objectives, encourage all to communicate, and take into account the diverse cultural backgrounds of the respective members.
11. Assign members specific actions and steps to carry out (e.g., analysis, focus group inputs, activity-based costing).
12. Organize field trips, on-site visits, and other activities needed to collect data and to observe customer practices.
13. Engage outside consultants and other resources to provide benchmarks, suggest alternatives, or overcome bottlenecks if needed.
14. Solve problems, resolve conflicts, and secure support functions needed for all team members.
15. Issue regular reports to all regional managers concerning the team's progress and team member performance.
16. Strive to achieve a consensus on major issues, making sure that the outcome serves as a valid solution to the problem under consideration.
17. Submit the final outcome of the team to the company president or to other upper management, and gather the whole team to make a formal presentation of the results and to celebrate the successful completion of the team effort.
18. Document the experience and preserve the learning gained by the team effort, using inputs from all team members.
19. Gather the whole team to celebrate the team success.

13.7.3 Management Style (Most Useful for Global Opportunities)

Management style plays a critically important role in globalization, because globalization makes communication and personal interaction necessary between people of different cultural, business, and personal backgrounds. For example, American managers may grow up in hierarchical and command-and-control systems. They typically perform thorough competitive analyses, using strong analytical tools and strategic audits. They focus on short-term profit objectives. They value being goal and achievement oriented. A great number of them are competitive, aggressive, ambitious, and intolerant of poor performance. Their management style is also influenced by American education, politics, and internal and external reward systems. In contrast, the Japanese management style is characterized by teamwork, market share objectives, commitment to quality, and a philosophy that says, "The nail that stands up gets pounded back down."

It is thus important for managers of global companies to recognize and accept extreme differences in management styles practiced by people in different geographical regions. In fact, there is no style—American, Chinese, Japanese, German, French, or British—that must be rejected. To be successful in a global economy, a manager must accommodate the priorities of other cultures by stressing shared goals and a common outlook; remaining open-minded; adapting to the local culture, business practices, and value systems; and avoiding both cultural and intellectual arrogance (Schneider 2014; Brett 2014).

Companies involved in global businesses typically change their management styles over time. Initially, some global companies direct worldwide activities in accordance with the home-country standards, adopting central decision-making and control paradigms. As the global companies increase their foreign investments, home-country standards become a reference basis for managing worldwide operations, and a model of decentralized and autonomous global operations will develop. Gradually, the global companies build a global network and follow a transnational strategy that is integrated and interdependent.

Example 13.4

In pursuing global business, one commonly practiced strategy is to elicit the maximum possible collaboration with the right business partners in the host country. This is because their local knowledge is of tremendous value in facilitating the adaptation of foreign-made products or services to local market needs and for problem solving. Creating trust among the partners will naturally be a critical first step toward implementing such a strategy.

What are some American management practices that can be counterproductive in winning the collaboration of foreign partners?

Answer 13.4

As background information, Table 13.2 contrasts the typical American management practices with those of the Japanese.

The following list describes some of the American practices that could be counterproductive in winning the collaboration of foreign business partners:

1. Exhibiting a highly competitive and arrogant personal demeanor and an ignorance of local culture, customs, and other differences in business practice, alienates the foreign partners. Here are two examples of well-known language blunders: (1) an "escrow account" in English means a "gyp account" in French. (2) When an issue is 'tabled" in America, it means that it is not to be brought up again; but in England, it means the exact opposite—that it will be brought up.
2. Being highly impatient and pushing aggressively for instant decisions fails to allow time for the foreign partners to create group consensus regarding the decisions at hand.
3. Emphasizing short-term profitability is a barrier to recognizing the business goals of the foreign partners who seek long-term, broad-based collaboration.
4. Being proud of risk-taking, and exhibiting decisiveness, a command-and-control rationale, and an excessive profit motive, fails to recognize that the values favored by the foreign partners might be different.
5. Adopting the "ugly American syndrome" that makes American managers insist that foreign partners do exactly what Americans do.

TABLE 13.2

Management Practices

	United States	Japan
Employment	Short-term	Lifetime
Decision-making	Individual	Group consensus
Responsibility	Individual	Collective
Evaluation	Rapid	Slow
Control	Explicit formal	Implicit informal
Career path	Specialized	Nonspecialized
Concern	Segmented	Holistic

13.7.4 Strategic Pathways to Globalization

Companies pursue globalization along any or all of geography-based, product-based, customer-focused, and Internet-based pathways.

The *geography-based pathway* is a pathway in that companies pursue globalization in geographical areas that have common cultural and linguistic ties—Canada and England for U.S. companies, China for Taiwanese companies, Southeast Asian countries for Chinese companies, and African countries for French companies.

Following the *product-based pathway*, companies conceive and perfect specific products that do not require local customization. The companies then distribute the products globally wherever there is a demand for them.

According to the *customer-focused pathway*, global companies follow their major clients to foreign markets with a basket of products to serve the needs of the local customers of these clients more efficiently. Examples of such baskets of products include the combination of insurance, banking, and securities offered by Citicorp to Citigroup's customers in China, Brazil, and other countries, and that of logistics and inventory management used by FedEx to FedEx's customers in foreign countries.

The *Internet-based pathway* prescribes that companies devise a web presence and leapfrog over other competitors to reach end users in numerous global markets.

13.7.5 Globalization Mistakes

There are a number of mistakes commonly made by companies pursuing globalization. Among them is a lack of company commitment, when companies do not make a firm and sufficient corporate commitment to people, capital, and time; and low management attention, when senior managers get involved only when there is a crisis affecting earnings. Oftentimes, companies assign low priority, viewing the international businesses as "incremental," and do not engage foreign partners decisively (take a minority position when entering a joint venture with local partners). Should the business relationship turn adversarial, these companies can get blocked out of the target markets; thus, one should always attempt to keep 50–50 ownership to stay even.

"Thinking globally and acting locally" is regarded as a best practice for a global company to keep things in perspective while achieving practical results. Without an international perspective, global managers have a disadvantage in the global economy of the twenty-first century (Garten 2000).

A lack of cultural sensitivity and understanding has been known to be a major source of frustration for global managers. An American in Japan is described in the following example (Glover et al. 2002):

> A young American manager was sent to Japan to work with the Fuji villagers on a forest project. During his first week in Fuji, he requested a local village chief to send "three men to do an eight-hour job clearing a field." Each of the three men was to be paid an hourly wage. The next morning, 40 able-bodied men from the village showed up to do the work. The American manager asked the group to select three men, reasoning that, as he did not need all 40 of them, he would send the remaining 37 back to the village. The chief responded that, if all 40 of them cleared the field, they would complete the work in one to two hours and then could go back to the village to do other work. Furthermore, the chief requested that the men not be paid individually. He would take the money and put it in to the village fund, a traditional communal means for distributing money equally. The American manager sent the chief and all of his 40 men away

and paid higher wages to three Fujian Indian contract workers he got from a nearby city a week later. He complained that the Fujian villagers were not motivated to be productive and they did not seem to have any individual initiative.

This was clearly a case of a cultural clash between the occidental approach to productivity based on "scientific management" and the oriental approach of getting the work done in a speedy manner by a collective work group. Their culturally conditioned views of productivity were different. The American manager was trapped in the "one best way" he believed in, namely, "three people to do an eight-hour job." He was unable to see possibilities of adapting to the concern of the chief, who needed to secure external funds to augment the overall village operations, while delivering work at a faster rate by using all of his able-bodied men. The chief thought it ought to be the same to the American manager, as the total cost remained the same, whether the work was done by 3 or 40 people, as long as it would be at the same hourly wage rate. Thus, the chief was equally frustrated by this exchange and viewed any future interchanges with this inflexible American manager with suspicion from that point on.

Example 13.5

In the 1980s, a lot of multinational companies were eager to conquer foreign markets. In a hurry, they committed a large number of culturally insensitive blunders, contributing to major marketing and business failures at the time. Name a few such embarrassing examples.

Answer 13.5

The examples of culturally induced mistakes are plenty. Reviewing them from time to time is useful only for the purpose of preserving the learning opportunities they offer (Kaynak and Herbig 2013):

1. *Chevrolet* introduced the "Nova" in Puerto Rico and found out only later that *No va* means "doesn't go" in Spanish.
2. *Ford* introduced a low-cost truck, the Fiera, into some emerging economy countries without success. It turns out that *fiera* means "ugly old woman" in Spanish.
3. *Esso*, the oil company, went to Japan. The phonetic pronunciation of *Esso* in Japanese means "stalled car," which was not helpful in promoting the sales of gasoline there.
4. *Cadbury Schweppes*, an English food company, introduced its Rondo soft drinks into the United States. It failed badly, although it was a success in England. Later, they found out that people in the United States thought Rondo was a dog food.
5. *Rolls Royce*, before Mercedes acquired it, marketed a car called "Silver Mist." When that name was translated into German, the "mist" became "excrement." It forced Rolls Royce to change the name.
6. *McDonald's* promoted its food products in Japan using white-faced clowns at one time. White face in Japan is a death symbol.

13.8 Globalization Drivers

There are a number of driving forces present in the global economy. Each company may be driven to globalization by a different set of drivers, such as market reach, cost, competition, and government.

Market drivers include worldwide increases in per capita income that result in greater purchasing power and an increasing demand for products/services worldwide. Another market driver is the convergence in lifestyles, tastes, aspirations, and expectations of consumers. An additional market driver is increased global travel, which brings about a new class of global consumer. A further market driver is the creation of larger future markets in emerging countries. Over 90% of the world's population is outside the United States. Companies need to pursue globalization to reach these extended markets (Brady 2014; Johansson 2008). To be located close to customers is an important corporate marketing strategy. There are about 17 automobile assembly plants built by foreign carmakers on American soil. As recently as June 2003, Nissan motors announced an investment of $250 million to relocate its production facilities of the Pathfinder SUV (2005 model) from Japan to Smyrna, Tennessee. This relocation program would create 1500 new jobs in the United States. Also well known are the investment examples of General Motors, Ford, and Volkswagen in China, and Renault in Japan.

Cost drivers include lower manufacturing and production costs (due to lower labor costs), economies of scale, accelerating technological innovations, and upgraded transportation and logistics. Some companies seek a cost advantage as the primary motive to go global.

Competitive drivers include (1) global competitors with speed and flexibility; (2) the increased formation of global strategic alliances, resulting in a proliferation of partnership relations with suppliers, customers, and competitors (Culpan 2002); and (3) more countries becoming attractive marketing battlegrounds. Creating competitive advantages is the principal goal for some companies to pursue globalization.

Government drivers of globalization include (1) the emergence of trading blocks (EU, NAFTA), (2) a large scale of privatization (Brazil, China, etc.), and (3) a reduction of trade barriers (WTO). Companies go global to take advantage of the benefits made possible by these official or semiofficial government bodies.

Ernst & Young conducted a survey of more than 300 CEOs in 1993. The top 10 drivers in the global race were recognized as follows: (1) increased speed of delivery to customers, (2) enriched ties with strategic partners abroad, (3) enhanced support of domestic customers' international operations, (4) meeting of cultural needs of foreign customers, (5) access to new technologies, (6) avoidance of overseas protectionism, (7) reach for lower taxes and government benefits, (8) access to foreign technical and management talent, (9) utilization of low-cost labor, and (10) avoidance of domestic regulatory constraints.

Indeed, numerous forces of significant magnitude are driving companies toward globalization.

13.9 Implementation Issues Related to Globalization

When pursuing globalization, the management of global companies can benefit from the international business experience gained by other companies. This section addresses emerging issues and the ways some global companies conduct global business.

Global companies face two emerging issues. The first is *fairness*. Traditionally, in the market economy, major multinational profit-seeking companies have pursued globalization. Home-country governments of these companies tend to set the macroeconomic policy and rules of the game, and they do not always have the interests of emerging economy countries in mind. Calls have been issued by some emerging economy countries to seek global governance, with the participation of all emerging economy countries in order to ensure fairness to all involved.

The second issue is *conflicts of interest*. In industrialized countries, workers in certain "old-economy" sectors (e.g., mining, textiles, agricultural, and other manufacturing enterprises) face unemployment when jobs are transferred to emerging economy countries that offer lower labor rates. Workers in the "knowledge economy" sectors—electronics, computers, and high-tech export businesses—are gaining. Surveys indicate that people with low incomes are generally opposed to globalization, while those with high incomes favor it.

Protests staged against the WTO by the joint forces of labor (stumping for work rules to protect U.S. jobs), environmental (promoting the reduction of pollution), and human rights groups (protesting for the elimination of political and religious suppression) at various international places in recent years have indicated clearly that not everyone is in favor of globalization.

Even inside emerging economy countries (e.g., China), globalization is not welcome by all. Increased privatization, foreign investment, market opening (telecommunications, banking, financial services, and others), and increased foreign trade can facilitate the destruction of countless existing state enterprises and thus cause massive unemployment in the state sector. Hence, globalization brings gains to some sectors and losses to others, as discussed previously. Global companies need to devise long-range programs to address these issues in order to sustain the benefits they realize from globalization.

Companies engaged in international business may be classified into one of the four groups listed next, according to their corporate behavior in conducting global business.

13.9.1 Defender Companies

These companies are internally focused. They have no global orientation and no international vision in their business strategies. They are focused on domestic markets and make no effort to understand other markets and cultures. They have limited skills and knowledge to pursue foreign markets. They look to governments to provide protection against foreign intrusion (e.g., through trade barriers, quotas, duties, laws, and special agreements). Their view is, "What is different is dangerous." Examples include (1) the U.S. steel industry, which sought quotas from 1960 to 1980 to restrict Japanese steel imports to the United States; (2) the U.S. footwear industry, which attempted in vain in 1980 to get import protection; and (3) the U.S. textile and machine tools industries, which got government relief against imports in 1975. Today, many of these industries are under the protection of bankruptcy laws or import tariffs. Some of them have barely survived under governmental subsidization programs.

13.9.2 Explorer Companies

These companies are largely inwardly oriented, with dominance in the domestic markets. They are aware that opportunities may exist abroad. They move into foreign markets very cautiously after closely studying the opportunities available. They have some knowledge about the markets abroad and possess a restricted set of skills to pursue them. Overall, they have small international business revenues. The home-based headquarters controls their businesses. They may pursue some export and franchising activities, but with rather limited investment commitment. Companies in this category include Seiko and Lotus (both of which have been acquired by Microsoft).

13.9.3 Controller Companies

These companies are more externally oriented than the explorers. They want to control the market abroad. They have sufficient knowledge and skills to pursue foreign markets, but have a limited global mind-set. They generate a significant amount of overseas sales revenues with major investment commitment. They impose their home culture and practices on overseas operations, although they do tailor some strategic decisions to suit the local cultures or to optimize the interests of their home office and the local markets. They maintain financial and strategic control at the home office, while allowing some independence in overseas activities. Examples of companies in this category include Coke, McDonald's, and Pizza Hut.

13.9.4 Integrator Companies

These companies have a global perspective based on heightened awareness (knowledge) and strengthen abilities (skills). They form a worldwide web of relationships, partnerships, and alliances with suppliers, developers, designers, distributors, competitors, and customers. They reconfigure these relationships over time as new threats and opportunities arise. They coordinate, rather than control, these networks of business partners. They focus on overall organizational effectiveness in delivering products/services of value to customers. They understand, bridge, and resolve differences between people, companies, values, and cultures. Their core strategy is to win in the marketplace by leveraging, sharing, and nurturing complementary capabilities. In this group of companies, General Electric, Toyota, and Hewlett-Packard are known to have formed networks with primary, secondary, and tertiary suppliers and subcontractors. To be globally successful, companies need to walk, talk, and act like integrators.

13.10 Quality of Global Leadership

Global management is demanding. According to Lamberton (2002), global managers must possess certain characteristics and savvy to be successful in a global environment.

Global business is highly complex and uncertain, due to variations in cultural, linguistic, political, social, and economic conditions. Global managers must constantly learn in order to succeed. Constant learning requires an inquisitive mind. Successful global leaders are adventuresome, curious, and open-minded. Inquisitiveness strengthens personal growth, characterized by emotional connection to people and uncompromising integrity; and duality, the capacity to handle uncertainty and the ability to balance tensions. Personal integrity inspires staff trust and commitment, which in turn affect the implementation results of any global strategy.

To be effective in global business, managers need to have a global mind-set, which will enable them to do the following (Jeannet 2000):

1. Extend concepts and modes from one-to-one relationships to holding multiple realities and relationships in one's mind simultaneously, and then act skillfully on this more complex reality (global think).
2. Change management orientation from taking individual initiatives to adopting team and group initiatives.

3. Focus simultaneously on hard issues (low-cost producers, bottom lines, budgets, manufacturing, marketing, distribution, head count, and finances) and soft issues (value, culture, vision, leadership style, innovative behavior, and risk taking).
4. Balance the pressures of global integration (product standardization) and local responsiveness (adjusting to the needs of local markets). Recognize the interdependence of the global economy and view the world from a broad perspective. Seek trends that affect company business, balance contradictory forces, rethink boundaries, and build and maintain organizational networks at the global level.
5. Serve as a catalyst within the company, being sensitive to, and capable of, managing cultural diversity. Become more tolerant of other people and cultures. Consider culture diversity an asset. Connect emotionally with people and the worldwide organization. It is worth noting that European managers are said to be more accustomed to exposure to cultural diversity than American managers.
6. Recognize complex patterns in the global environment and thrive on ambiguity. Become proficient at managing uncertainty and dealing with conditions that change constantly and are inherently complex.
7. Preserve a unique time and space perspective. Take a long-term view, extending personal space in geography and relationships.
8. Exhibit business and organizational savvy. Recognize opportunities, grow in knowledge of available resources, and be capable of mobilizing them to take advantage of opportunities.

Global managers must possess specific knowledge and capabilities to succeed. They should have a mastery over technology (information systems, telecommunications, and operations) and use it effectually. They need to be aware of the social and political features of different countries. They should be familiar with the specific culture and cross-cultural issues that affect management. Of great importance is their understanding of the global competitive practices in manufacturing and communications, such as total quality management, just-in-time delivery, factory automation, employee involvement, and outsourcing. Also helpful is some general knowledge about business and industry and the skills required to put knowledge into action, to become acculturated, to lead, and to motivate a diversified workforce.

Of critical importance to global companies is the business savvy of their global leaders to size up business opportunities and to have a vision of doing business worldwide.

1. *Recognize global market opportunities*: The ability to recognize new opportunities is a key leadership quality of global managers. They need to be able to do the following:
   a. Assess the cost and quality differences in production outputs and inputs, and exploit cost differentials for land, energy, labor, raw materials, and people talents.
   b. Identify market needs for goods and services from a deep and broad knowledge base, having mastered finance, accounting, marketing, human resources, operations, international relations, economics, industry conditions, and strategy disciplines.
   c. Size up opportunities for efficiency gains by (1) eliminating redundancies to wring out costs, (2) using economies of scale in procurement, (3) pursuing standardized outputs, and (4) selling to multiple markets.

d. Create competitive advantages by forming supply chain networks involving strategically selected, local and global partners with complementary resources and expertise.
2. *Envision doing business worldwide to ultimately make money*: The manager should also have a good overall perspective of what the company's business has to offer—what the core is, why the core is what it is, and what drives the core. This understanding is combined with the fundamental good business goal of making money for the company.

Global managers are required to demonstrate organizational capabilities. These capabilities are built on specific qualities:

1. *Know your company*: Global managers must have an intimate knowledge of their own companies with respect to subsidiaries' product lines, cost structures, and overall competitiveness. They should know the location and quality of the technological resources available, including physical assets and managerial and employee talents. Global managers must be known to the company's key decision-makers by having served on key committees, participated in task forces, and attended critical meetings.
2. *Mobilize resources*: Global managers need to be able to mobilize resources to take advantage of global opportunities. Establishing trust with top management and key decision-makers will ensure their favorable response to these mobilization efforts.
3. *Develop insight*: Global managers must be able to identify critical knowledge and capabilities beyond merely understanding policies and programs.
4. *Keep current*: Global managers must keep themselves constantly informed of what is presently going on at the headquarters.

Global businesses require managers to be patient with, tolerant of, and open-minded toward divergent cultures, customs, and business practices. They should be dedicated to the mission at hand and assume a flexible negotiation style to win. They should possess stamina to endure personal hardships, the personality to effectively handle uncertainties and ambiguity, and the conviction that what is different is not necessarily dangerous (Dalton et al. 2002; Marquardt and Berger 2000; McCall and Hollenbeck 2001).

The manager needs to recognize that, for global businesses to succeed, the new model of responsiveness, partnership, teamwork, and decentralization must replace the early management model of efficiency, hierarchy, control, and centralization.

Not everyone has the desire to become a global leader. Those who want to be global leaders need to become proactive in seeking opportunities for leadership development. Personal preparation can assist in refining these desirable traits.

13.11 Production Engineering in a Global Economy

Global companies needs to scale down the capital investment for production, shorten the time to market, change product features flexibly to meet the requirements of the changing local markets, ensure product quality, and offer after-sales support and services to maintain long-term profitability. As a result, production engineering will experience significant changes in the global economy.

To compete effectively on a global basis, companies need to aggressively engage partnerships, form supply alliances, and create networks with domestic and international suppliers of raw material, subassemblies, semifinished goods, and others to make finished products flexibly and speedily (Culpan 2002). The production engineering issues involved in global environments will be significantly different from those in traditional old economy companies.

In old economy companies, where vertical production has been the norm, production engineering deals with the manufacturability of products/services and the application of resources (technologies, labor, materials, plan layout, utilities, etc.) to optimize production.

In the knowledge economy, in which global companies pursue production via networked partners, each having its own production capabilities and engineering, production engineering will need to deal with issues in different ways. Some of these issues and methods are as follows:

1. *Product design and specification*: Communicate and enforce interface specifications of all parts produced by the partners. Standardize interfaces to promote the exchangeability of parts in order to offer different product features. Effect infrastructure and hardware and software systems to facilitate supply chain management. Integrate middleware, electronic data interchange (EDI), systems technologies, regulations, production practices, and others to improve efficiency.
2. *Manufacturing*: Selectively apply web-based enablers in manufacturing and operations to gain advantages. Produce core parts, and assemble the finished products with vendor-supplied parts. Refine an assembly procedure to safeguard product integrity. Conduct statistical process control (SPC) to ensure system quality of the assembled, finished products. Pursue the International Organization for Standardization (ISO) and other quality process certifications of networked partners.

   With GE's example of "continuous mobility" as a guide, companies should explore ways to have quality products made at locations where the loss is lowest. To implement such a manufacturing strategy, production engineering at headquarters must be prepared to transfer manufacturing and technologies processes to new recipient groups whenever needed.
3. *Management*: Share information and foster collaboration between the networked global partners. Preserve knowledge and apply global experience and learning. Strengthen a customer relationship management system by tapping into the expertise, innovation, and knowledge base of the networked partnership. Assist in setting up an enterprise resource planning system to optimize the utilization of corporate assets. Make the production process transparent to, and traceable by, customers.
4. *Logistics*: Ensure just-in-time (JIT) delivery and optimize transportation logistics.
5. *Inventory control*: Balance loads between global sites to adjust to changing supply and demand and marketplace conditions.
6. *Risk management*: Respond to labor, politics, currency, and unexpected changes and conflicts.

Boeing is well known to have implemented an ambitious supply chain strategy in producing its new 787 Dreamliner airplanes by

1. Engaging suppliers from 10 different countries, including Australia, Canada, China, England, France, Italy, Japan, South Korea, Sweden, and the United States.
2. Making use of vendors' unique expertise in designing and producing specific components (e.g., electronics and composite materials aerial processing).
3. Safeguarding of innovative design features.
4. Focusing on producing subassemblies to facilitate the speedy final airplane assembly, with the target of reducing the plane assembly time for seven days (for 737 planes) to three days (for 787 planes).
5. Controlling the life-cycle costs and delivery speed in order for Boeing to better align with the changing business cycles of the air travel industry.

To succeed in implementing such a complex supply system, Boeing spent a considerable amount of extra effort in preplanning, coordinating, problem solving, quality controlling, and transportation logistics. In the end, Boeing was successful in delivering its new airplane as originally designed, with the exception of having suffered a total delay in schedule of about three years.

13.12 Job Migration Induced by Globalization

Globalization has a profound impact on jobs, and many jobs are migrating to and from the United States as the push for globalization intensifies. For example, when foreign products (such as textiles, shoes, toys, and cheap electronics) overwhelmed U.S. markets in the 1980s, some American workers suffered. When Japanese automakers set up shop in the southern part of the United States in the 1990s to compete against Detroit carmakers, their investments created new jobs for American workers. When Nokia expanded its cell phone business into the United States, American workers benefited.

Besides reducing the cost of doing business, many companies outsource work to conserve investment capital; shorten time to market; build a variable cost structure; secure needed skills, technologies, and expertise; and realize a round-the-clock operation.

Over the years, a large number of American-based multinational companies have implemented strategies that cause engineering and other jobs to migrate to emerging economy countries. Even though engineering and blue-collar jobs related to manufacturing have been disappearing at an alarming rate, American manufacturing productivity has risen constantly over the last decade due to automation and a shift to higher-value work.

For the year 2002, U.S. productivity reached an annual growth rate of 9.2%, the highest worldwide. The U.S. Bureau of Labor Statistics (2004) has determined that outsourcing, to both overseas and domestic partners, has contributed about 1.5% toward this 9.2% growth. Innumerable U.S. firms are involved in outsourcing engineering and science-related work to developing countries. Engardio (2003) offers a comprehensive list of American companies engaged in outsourcing engineering and science jobs, including General Electric, Flour, Intel, Oracle, Texas Instruments, Hewlett-Packard, Boeing, and others.

Other big technology companies, including IBM and Microsoft, are bringing in foreign workers to America on L-1 visas, which allow the companies to pay workers their home-country wage rates for as long as seven years. The federal government places no limits on the number of L-1 visas issued to a company (Bridger 2003). Ford announced its plan to purchase auto parts worth $1 billion from China in 2004. With the stroke of a pen, Ford shifted thousands of jobs to China.

A large number of companies are also engaged in outsourcing various nonengineering jobs overseas (e.g., customer service, microbiology research, tax return preparation, back-office support, IT applications, and CT scan interpretation work). In fact, McCarthy (2002) predicted that 3.3 million U.S. white-collar jobs valued at $136 billion in wages will have migrated abroad by the year 2015.

The white-collar job migration is a serious problem that must not be overlooked. It is a moving train viewed by many to be unstoppable.

13.12.1 Global Pie Concept

Is white-collar job migration all that bad? It is certain that some white-collar workers will be adversely affected. Some analysts believe, however, that the overall impact of offshoring may actually be positive for both the United States and the world at large. Agrawal and Farrell (2003) estimated that the benefit of about $1.45 may be derived from $1 spent by America in offshoring, suggesting that the global pie will be made bigger, not smaller, by offshore investments. The key point is, of course, that the offshoring of investments is not predicted as a zero-sum game, wherein the gain of one party is at the expense of the other. Rather, both parties are expected to benefit in the process.

13.12.2 How to Survive White-Collar Migration

Agrawal and Farrell (2003) assume in their studies that the value of U.S. labor reemployed is $0.45–$0.47 for each U.S. dollar invested in offshoring. This means that the investment funds freed by going offshore can be effectually deployed within the United States (e.g., hiring employees to do higher-value work and initiating leading-edge R&D).

Engineers whose jobs may be outsourced unexpectedly need to ask the question "What will it take for them to become part of these 'reemployed resources' that companies will want to use the freed investment to engage?" There are a number of steps that engineers may take to augment their relative competitiveness in this situation.

1. *Get advanced training*: Currently, white-collar jobs migrate primarily from the United States to four lower-wage countries: China, India, the Philippines, and Mexico. These recipient countries bring forth an overwhelmingly large number of engineering and science graduates at the BS level every year. In other words, the number of U.S. graduates at the BS level is predicted to become a smaller percentage of the five-country total—only 15%. Each U.S. engineer or scientist graduating with a BS degree will have six other engineers or scientists as competitors in the job market. Similarly, MS and PhD graduates in the United States will make up about one-third of the five-country total. Each U.S. engineer or scientist with an MS or a PhD degree will have only two others from the four low-wage countries to compete against.

   These numbers suggest that it would be useful for American engineers to get advanced degrees as one of several steps to decrease the adverse effects of

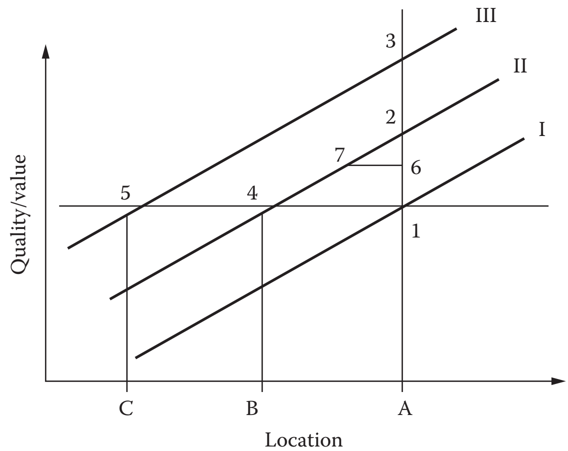

FIGURE 13.4
White-collar migration.

white-collar migration. Having an advanced degree is likely to be useful, but it is still not a guarantee that an engineer will survive the threat imposed by white-collar job migration.

2. *Practice the "steady-ascent" strategy*: Engineers should constantly seek to upgrade the ways that they perform their jobs, so that their employers can provide better, faster, and cheaper products and services to their customers. Innovations are desirable at the interface between engineering, design, and manufacturing to minimize labor, cut waste, enhance quality, and speed up time to market. The added value concept is quite ordinary in itself. However, it becomes critical in times of white-collar job migration (see Figure 13.4).

Quality and value versus location is plotted in Figure 13.4. The horizontal axis denotes production sites, from low cost on the left to high cost on the right. Production cost at A is higher than at B, which in turn is higher than at C. The straight lines I, II, and III symbolize the linear relationship assumed to exist between the quality–value combination and cost. It is reasonable to assume that the higher the product or service quality is, the higher its production cost will be. In the course of time, such a straight line shift from I to II to III, reflecting the constant strides made by developing countries in their capabilities of manufacturing products and supplying services at high quality, while keeping their wages at relatively low levels.

Let us assume that Point 1 is the current point of operation, with a quality–cost relationship depicted by the straight line I and its location selected at A (e.g., the United States). As the developing countries upgrade their engineering and production skills and become increasingly capable of supplying work of acceptable quality, the quality–cost curve available to U.S. firms moves from I to II. Under these circumstances, U.S. firms will logically shift production and other work from Point 1 to 4 and relocate the associated operations from A to B (e.g., to India or China), while keeping the quality at an acceptable level. Should another country offer even lower wages in the future, the U.S. firms will not hesitate to move their facilities again from B to C to operate at Point 5. This is consistent with the concept of "continuous mobility" practiced by General Electric and other firms. The relocation of operations from A to B and from B to C will ensure that the firms remain cost competitive over a long period, without sacrificing the quality of their products or services.

For individual engineers to ensure that they do not get displaced by white-collar migration, Figure 13.4 offers an obvious strategy. It is a given fact that the developing countries will constantly upgrade their engineering and production skills, as illustrated by the shifting of the straight line from I to II to III. Therefore, in order for engineers to survive white-collar job migration, they need to periodically add enough value to ascend from Point 1 to 2 and from 2 to 3 while employed in the home country (A in this example). In fact, should the individual reach Point 3 after the quality–cost line II is reached, his or her job may be outsourced. Specifically, if the value contributed by the engineer reaches Point 6 rather than Point 3, then employers will seek to outsource the work to operate at Point 7, the lowest-cost operating point for the same value/quality.

The key message here is that engineers must pay attention to the rapid progress made by developing countries and use these external benchmarks as the correct yardsticks to measure their own performance so that the incremental value they add is always on par with or higher than that which can be readily gained by their employers through offshoring. Furthermore, this value must be added in time for them to remain competitive from the value–cost standpoint. Besides the magnitude of the value contributed, timing is critical. Engineers need to avoid being caught off guard in this dynamic environment. It is like rowing a boat upstream; resting means falling back.

Thus, the traditional mode of continuing education (e.g., taking a course or two from time to time) will probably not be sufficient to ensure job security. What is needed is fast learning guided by constant external benchmarking and adding value before equivalent value can be attained at lower cost (via going offshoring).

As global employers pursue continuous mobility, global engineers need to practice the steady-ascent strategy in a timely manner.

3. *Be selective*: Engineers are advised to be selective in choosing activities and functions that add recognizable value to their employers. Adhering to the following guidelines will make it more likely that engineers will be marketable at any given time:
   a. Stay close to the employer's core competencies, which are usually preserved and nurtured in-house.
   b. Learn to absorb complex information quickly and solve technical, business, and people problems creatively. Focus own work on maximizing its value added.
   c. Become versed in interacting with workforce members of diversified backgrounds. Baby boomers who are managing the current operations of many companies are expected to retire in the next two decades. The gap left behind by them will need to be filled by capable people who can direct teams of diversified cultural and business backgrounds (Kaihla 2003).
   d. Acquire the capabilities of designing and advancing the next generation of products and technologies and pursuing work that has high-innovative content. Apply new technologies to wring out product costs. Dell uses robots to

assemble computers quickly and reliably in the United States, negating some of the cost advantages of moving plants offshore.

e. Cultivate visions with originality and a global orientation, and demonstrate leadership in strategic planning.

f. Maintain a broad business network that can be tapped into to add value for challenging situations.

g. Avoid attaching yourself for too long to functions or activities that are readily outsourced. Study the industry. Stay away from labor-intensive “grunt” work—tasks that can be performed by following well-specified procedures and are more or less mechanical or operational in nature. Such work is easily learned and performed by other engineering graduates in low-wage countries. Examples include low-level engineering design, assembly operation, customer service, procurement, project management, troubleshooting equipment, engineering analysis using canned software programs, and laboratory tests.

13.13 Conclusion

Globalization continues to be an inevitable business trend in the twenty-first-century economy. Three of the top-five economies in the world are likely to shift to Asia by 2020.

Globalization creates ample value-added opportunities to those engineering managers who are properly prepared and equipped with the required global mind-set, knowledge, and savvy. Having a global orientation is no longer opulence, but a necessity for economic survival in any industry.

Adjustments are needed for American managers to become effective in the global arena. They need to become more tolerant of, and adaptive to, that which is foreign and different. Past experience can serve as a useful basis for guiding future progress.

Engineering managers are encouraged to continuously follow the globalization process, to become sensitized to all issues involved in globalization, to make useful contributions to high-value work, and to prepare to lead in the global economy.

QUESTIONS

1. For products intended for global markets, customers’ wants and needs are different from one market to another. How can a centralized global team build up a product to serve as a “platform” for the global market?
2. Japanese companies face challenges similar to those faced by U.S. companies in that low-cost manufacturing capabilities are readily available in such countries as China, India, the Philippines, and Mexico. How can the Japanese companies plan to deal with these challenges?
3. It can be argued that democracy and capitalism are concepts that are fundamentally incompatible with each other. Democracy is built on the principle of equality—one person, one vote—regardless of the individual’s intelligence, wealth, work ethic, or any other features that may distinguish one individual from another. Capitalism, on the other hand, fosters inequality. It uses incentive structures to encourage hard work and wise investment to realize differences in

economic returns. Because future income from investments (in human or physical assets) depends on current income, wealth tends to generate wealth, and poverty tends to constrain the individual's economic growth. The cycle is self-reinforcing: success breeds success, and failure compounds failure. "The economically fit are expected to drive the economically unfit out of existence. Thus, there are no equalizing feedback mechanisms in capitalism" (Thurow 1997).

What are some of the remedies capitalistic countries have introduced to mitigate such inequality? Would globalization compound this condition in a capitalistic and democratic country? Why, or why not?

4. Globalization, which causes the countries involved to become more interconnected, clearly has tremendous social and political implications. It also has a cultural dimension to it, due to worldwide communications that facilitate the global connections. Cultural globalization may lead to a more civic global society with a greater consensus on civic values. It may also diminish the rich diversity of human civilization, as the Asian, Islamic, South American, and other non-Western values become increasingly generic. For many, the preservation of distinct cultural traditions is a very serious matter.

   Is globalization a form of Western imperialism that may homogenize non-Western values? Why or why not? Can homogenization be avoided or mitigated?

5. During the new century, increased flows of products, services, technologies, capital, and workers across national borders will affect the economical, social, and political life of everyone involved. The UN is expected to play a critical role in this increasingly dynamic environment.

   In your opinion, what should be the major missions of the UN in addressing these issues?

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14

Engineering Management in the New Millennium

14.1 Introduction

Tomorrow's industry, due to advancements in technology and the increased sophistication of customers, will be quite different from that of the recent past (Groen et al. 2015). Advancements in communications technologies have made various business transactions cheaper, faster, and better at meeting customer demand. Web-based tools are available to foster information sharing and knowledge management, leading to improved supply-chain management, mass customization, benchmarking, customer relationship management (CRM), and e-transformation, on top of adding value to the traditional engineering functions (e.g., product design, project management, plant operations, and manufacturing) (Drucker 2013).

Rapid changes in production, service, and distribution technologies will continue to result in extensive organizational reform. Globalization will cause engineering organizations to be managed differently than in the past. It is important for today's science, technology, engineering, and math (STEM) professionals and leaders to proactively anticipate the future, recognize the significant changes lying ahead, and prepare to seize the new opportunities associated with these major changes.

In this chapter, we first contrast past engineering management in industry with that of the new millennium (Schmidt 1999). Specifically, we address the issues related to new trends emerging in our economy. The differences between companies in the old and new economies are reviewed. The characteristics of knowledge economy companies and their likely strategies are examined next. We then discuss the new types of workforce and the new responsibilities of managers in progressive companies. Finally, we outline the significant contributions expected of STEM professionals and leaders in these companies.

Business development is critical to the success of twenty-first-century companies (DePalma 2002; Johansson 2008). The extension of market reach is due primarily to globalization (see Chapter 13). Capable enterprises are constantly looking for new customers in emerging markets to expand sales, seek resources and location-based synergies to enhance their competitive advantages, and exploit economies of global scope to mitigate business risks. Reaching out to global markets will be a major driving force affecting innumerable engineering enterprises in the new millennium.

In this chapter, we also explore various management issues applicable to the marketplace and emphasize new challenges that STEM professionals and leaders are expected to face in the new millennium.

14.2 Future Trends

Before we talk about specific changes expected in industry, a brief review of some of the new trends (not related to globalization) in our economy is in order. Several major trends already noticeable in the knowledge economy have been brought about by the growth of web-based enablers and by the increasing demands of customers for better, faster, and cheaper products and services. The common underlying threads among these trends appear to be *effectiveness* (customer and environment), *efficiency* (internal structure and operation activities), and *integration* (one-stop consolidation). Discussed in this section are specific trends related to customer focus, enterprise resource planning (ERP) and application integration, supply strategy, knowledge management, changes in organizational settings, and population diversity.

14.2.1 Customer Focus

In the knowledge economy, customer service will be driven by several distinct characteristics (Anderson et al. 2000; Schmitt 2003):

1. *Speed of customer service*: It is preferable to reduce the processing time between searching, selecting, entering, and fulfilling orders. There will be no more excessive handoffs. Companies are moving toward a seamless integration of steps to accept orders, trigger receivables, send orders to production, route requisitions to warehouses, activate shipments by logistics partners (e.g., UPS, FedEx), replenish inventory, update accounting, replenish stock with suppliers, and track delivery status to ensure on-time delivery (Buss 1999).
2. *Customer self-service*: Companies involved in real estate, insurance, travel, car buying, auction, parts sourcing, and retailing are increasingly moving toward empowering customers to serve themselves by creating 24/7 (i.e., 24 hours a day, 7 days a week) systems and cutting out intermediaries. The following three companies are successful examples of the trend to encourage and empower customer involvement in self-service:
    a. Gateway: Customers define their own needs, configure systems, place orders, pay for new computers, and get limited support.
    b. E-Trade: Customers trade securities without broker involvement, using a 24/7 website.
    c. Microsoft Expedia: Customers make reservations online to book flights and receive confirmations at a lower cost, while enjoying faster service.
3. *Integrated solutions for customers*: Customers have moved away from best-of-breed individual solutions toward integrated systems. A specific example is Microsoft Office Suites with integrated functionality.

    Customers are motivated by the desire to spend less time shopping, shop at one-stop stores, make fewer shopping trips, and decide among fewer choices. The following are examples of organizations responding to these desires:

    a. Gap: A one-stop clothing and accessory provider that encourages convenience-based "package" purchases. Mannequins are outfitted with shirts, blue jeans, belts, baseball caps, sunglasses, socks, shoes, gloves, and a knapsack, marketing a hip image.

b. Citicorp: In 2002, this company started to offer the combined online services of banking, credit cards, automobile insurance, brokerage and investing, mortgage and loans, and e-mail cash for money abroad.

c. Automatic teller machines (ATMs): These machines are being expanded by countless financial institutions to include web-based services such as e-mails, online purchases, and transactions.

4. *Customized service and sales*: Statistics indicate that some companies lose 50% of their customers every five years. Generally, it costs 5–10 times more to obtain a new customer than to retain one. One approach taken by some companies is to train customer-facing agents to cross-sell and upsell.

   For example, Home Depot emphasizes service to do-it-yourself customers and provides customers with easy access to information. The company starts offering service before sales and continues its customer service after sales.

5. *Consistent and reliable service*: Customers prefer to have single points of contact, which requires the company's service calls to be coordinated with supply chain business partners (i.e., those members of the extended enterprise family under outsourcing, alliance, or partnership agreements).

6. *Flexible fulfillment and convenient service*: Gevalia Kaffe imports coffee and makes home deliveries. It performs 200,000 transactions per week and has built an e-business infrastructure to take orders, find the lowest-cost routing distance between the customer and the nearest warehouse, check inventories, issue shipping orders, and activate shipping by the networked partners who deliver coffee to home addresses.

7. *Transparent sales process*: Customers typically want to know the order status, product information, pricing, and availability (Larsson and Lundberg 1998). UPS is known to have set up a 24/7 sophisticated information system that performs the following functions:

   a. Tracks air and ground parcels at any time and from anywhere.

   b. Achieves flawless delivery, which is now becoming the norm rather than the exception.

   Another example is Solectron, which makes circuit boards and electrical assemblies for such customers as IBM, HP, and Intel and has plants in California, Washington, Malaysia, France, and Scotland. The company has refined a shop-floor tracking and recording system (STARS) that uses bar codes to enable customers to track the status of their orders. The enhanced process transparency helps create new demand while retaining satisfied customers.

8. *Continuous improvement in customer service*: Constantly learning new ways to enhance customer service is one of the key factors for companies to succeed in today's marketplace. For example, Nordstrom bends over backward to please customers with gold-plated service and a no-questions-asked return policy. This company found that 90% of its business comes from a loyal 10% of its shoppers. (This is an example of the Pareto principle, described in Section 5.8.) The methods Nordstrom applies to achieve a high degree of customer retention and sustainable innovation are outlined as follows:

a. Motivate employees by paying them very high rates of commission.
b. Use undercover shoppers to evaluate service and give cash rewards to employees who achieve a perfect score.
c. Delegate authority downward to allow autonomy and local decision-making.

Nordstrom's strategy is compatible with the *Service Profit Chain Model* (Heskett et al. 2010). This model is unique in that it originates from company leadership (e.g., vision, values, energy, concern, and discipline). Superior leadership creates a good place for employees to work (e.g., through workplace design, job description and latitude, selection and development, communication and information, and tools for serving customers), which in turn produces satisfied employees. Happy and productive employees serve customers better. In turn, satisfied customers buy more and create increased profitability for the company.

9. *Technology-enabled services*: The trend is toward an integration of various means of access available to customers, such as the web, direct dial-up, interactive voice response, and kiosks.

   For example, customers are projected to be in the driver's seat in influencing the development of IT technologies (Moschella 2003). The waves of IT technology move from a technology-centered paradigm to a customer-centered practice.

The first, system-centric, wave focused on developing proprietary systems. The second, PC-centric, wave centered on working out the hardware and software standards. The third, network-centric, wave dealt with Internet standards. The fourth, customer-centric, wave addresses the information content and transaction standards. This last wave aligns more closely the values of IT technologies with the needs of customers.

14.2.2 Enterprise Resource Planning and Application Integration

In the past, companies concentrated on achieving optimum performance in various individual functional departments. Each of these departments had a tendency to pursue optimal operations within its own boundaries. Each department, similar to a silo, acted like a tightly controlled organizational unit with limited communications capabilities to the outside world across its boundaries, except through its top. In practice, the deficiencies created by poor, uncoordinated transactions between the functional groups more than offset the benefits of the local optimization they achieved. Thus, over time, it has become evident that corporate competitive advantages can be achieved only through the proper integration of the individual functional departments of, for example, engineering, manufacturing, design, customer service, procurement, finance, and accounting. Today's trend is toward enterprise application integration (Myerson 2001).

An integration of disparate departmental functions permits greater access to information, while linking employees, business partners, and customers more effectively. There are many enterprise application software products on the market that facilitate such integration. The obvious benefits created by this type of integration are speed, accuracy, and cost reduction, because of reduced manual handoffs (e.g., manpower), which allows business decisions to be made faster, at higher quality and lower cost.

1. *Integrated communications systems*: The trend is toward an integration of networks composed of telephones, cable TV, wireless, and computer data. The "last mile" bandwidth problem (from telephone switching in the office to the home) will

likely be solved using fiber-optic systems. AT&T, Sprint, and MCI/Worldcom are said to be working on the integration of voice and data services

Browsers and modems are used as customer home contact points today. WebTV could very well replace these in the future.

2. *Wireless applications*: The use of airwaves for other services in addition to phone calls is expected to increase. Data transfer to mobile units allows managers and leaders to make important decisions from anywhere at any time. For example, Palm Pilot (3Com) is a two-way personal communication tool in text format that displays real-time flight schedules, news headlines, and online transactions (such as movie ticket purchases, stock trading, etc.). The Nokia 9000 Communicator is a phone, web browser, and personal-messaging and data-organizing system. Apple's iPhone 6 and iPhone 6 Plus systems enjoy much acceptance in the marketplace.
3. *Leveraged legacy systems*: Middleware consists of connectivity products that link the existing legacy systems on mainframe computers with clients and servers and the Internet. Middleware performs the important function of making existing data widely available to employees and customers

14.2.3 Supply Strategy

Traditional enterprises create vertically integrated organizational structures and amass heavy physical assets to achieve competitive advantages in the marketplace. Knowledge-economy companies form flexible supply chain partnerships to increase the speed to market and vary the product/service features to better satisfy the ever-changing needs of customers. Use is made of the technological and marketing expertise of the networked partners. Competitive advantages are thus derived from their capability to form such knowledge-intensive business networks, rather than from the value of capital assets piled up on the ground (Chopra 2015).

Outsourcing is a major trend that favors the formation of virtual enterprises. A single company working alone is no longer viable, as diverse competencies are needed to compete in today's marketplace. In these virtual enterprises, certain noncore business processes will be strategically outsourced to achieve higher earnings and more pronounced competitive advantages. Examples include

- Niagara Mohawk, which outsources human resources and purchasing functions
- United Technologies and American Express, which outsource their procurement functions to IBM

Other companies have started outsourcing many of their noncore operations, concentrating instead on doing what they do best. For example, Sun Microsystems has focused on design, electing to contract out or purchase all workstation components. This strategy permits Sun to (1) introduce new products rapidly, (2) achieve better quality, (3) ensure dependability, (4) shorten speed to market, (5) gain flexibility, and (6) realize cost advantages.

Another example is Sara Lee, which focuses on building new products, managing brands, and building market share, while outsourcing the production of Leggs hosiery, frozen desserts, Wonderbras, Coach briefcases, and Kiwi shoe polish.

In essence, this strategy allows the company to jump on and slide down someone else's experience curve (e.g., Boston Consulting Group's 85 % curve) (Figure 8.13) to maximize benefits while maintaining flexibility in switching partners.

The current push for better asset utilization (return on assets [ROA]) helps move companies toward becoming knowledge intensive (through supply chain and marketing), rather than capital asset intensive (through in-house production). Better asset utilization can be achieved by creating contract partnerships, setting up global production networks, keeping overhead costs low, changing products frequently, and innovating through technology.

U.S. companies that market products to end users have also started to outsource such corporate functions as production, back-office work, logistics, after-sales service, procurement, inventory management, and new product design. As this outsourcing trend continues, more demand is created for such service functions. The economy of scale dictates that new, vertically integrated product/service providers are likely to be created for the following purposes:

1. Vertically integrated parts suppliers are becoming huge multinationals in their own right, and they are tightly integrated to create efficiency (e.g., Delphi Automotive). Their factories are designed to be quickly rearranged in order for the same shop to make different products for different client companies. The focus is on manufacturing products and operating at capacity almost all the time. They get cheap components by buying in quantity. Parts may come from various regions of the world. Their gross margins are relatively small (6%–8% on sales), but they generate good return on equity (e.g., 20%).
2. Integrated service organizations take orders from banks, automakers, and pharmaceutical companies to handle financial advisement, accounting, and other services. Services offered to different industries are now bundled together. Certain design service providers may have teams of industrial, mechanical, and chip engineers scattered around the world.

STEM professionals and leaders in these product/service provider companies will need to work in an interdisciplinary environment, as dictated by the companies' mission to serve clients in different industries. Since these product and service providers conduct no R&D, perform no marketing, and develop no products, product innovations will have to come from their client companies' own R&D departments or from third-party start-ups.

Managers in the client companies will need to learn how to supervise the interactions between diversified product and service providers, and to ensure that their breakthrough idea—now entrusted to an outside provider to implement—will not benefit the competition.

14.2.4 Knowledge Management

Knowledge management refers to activities related to the preservation and enterprise-wide application of corporate expertise and know-how to create competitive advantages (Tiwana 2015; Hislop 2013).

Business success depends on innovation and the expertise of competent knowledge workers, whose insights need to be properly preserved by documentation, knowledge sharing, recruitment, and retention. The importance of knowledge management is becoming increasingly evident in the knowledge economy, wherein knowledge-intensive companies forcefully strive, as a corporate strategy, to attract talented and more mobile knowledge workers.

14.2.5 Changes in Organizational Settings

There will be two broad types of corporations in the near future. The first type generates and markets products and services to consumers (the end users). These companies retain core competencies and outsource everything else to selected service providers. A network of contract partners may produce the products or services, each being particularly efficient and outstanding in supplying specific components or elements. Outsourcing will succeed for these companies, as it has for Dell Computers, with products that are more than adequate for the customers and that are composed of current technologies available from the company's networked partners. Outsourcing requires a perfect understanding of what customers need and how the products are specified. Under these conditions, companies compete on the basis of speed, flexibility, and cost. Going virtual is thus becoming useful. This is a major change in organizational settings, moving toward the virtual organizational settings and away from vertical integration.

The other type of corporation will supply specialized parts, designs, and services to client companies under contracts. Acquiring various manufacturing facilities and organizing them into vertically integrated enterprises are the primary functions of these companies. Their manufacturing plants are laid out in a flexible manner in order to respond to the divergent needs of global clients. This is a second change in organizational settings moving toward additional vertical integration.

Some virtually organized companies are swinging back toward vertically integrated operations to perform their creative and developmental tasks. The reason for this is that, to achieve breakthroughs in products and technologies, innovative performance is needed. Usually, virtual companies do not have sufficient information or resources to enable their networked partners to make parts for innovative products. On the other hand, a vertically integrated company can readily amass all of the needed resources under one roof and thus can be effective in developing new products/services. Cisco Systems has integrated its operations to develop new fiber-optical networks. So the pendulum swings back a little, from virtual to vertical integration, for those companies that intend to come up with innovative products.

Not all companies should become virtual; neither should all functional elements of a company be vertical. The organizational form may have to be frequently adjusted according to the company's objectives, strategies, and changing environments.

14.2.6 Population Diversity

The U.S. Census Bureau predicts that there will be significant shifts in the American population by 2050. Specifically, whites (non-Hispanics) will decrease from being 69% of the total population in 2003 to 50.1% in 2050, blacks from 12.6% to 14.52%, Hispanics from 12.53% to 14.52%, and Asian/Pacific Islanders from 3.86% to 7.86%.

For example, the projected increase in Hispanics is due primarily to immigration. As a consequence, the U.S. workforce is expected to become more diverse (Ferdman 2013; Chin and Trimble 2014). Managers may need more diversity training, as more women and minorities are expected to attain key positions.

The trends described in this section have become noticeable in the marketplace since the turn of the millennium. All of these trends have important effects on how business priorities are set and how companies are run. In the sections that follow, some of the anticipated changes will be elucidated, along with the challenges facing STEM professionals and leaders in the new millennium.

14.3 Old Economy and Knowledge Economy Companies

Engineering enterprises in the old economy differ from those in the knowledge economy in many ways. These differences, which are briefly discussed in other chapters, are reviewed next (Capodagli and Jackson 2001).

14.3.1 Old Economy Companies

Typically, old economy companies are of a pyramidal structure. From the top, the CEO directs the company president, vice presidents, directors, and managers to lead, plan, organize, and control the workers at the bottom. The hierarchies are rigid, and the company boundaries are clearly marked.

These companies are capital intensive. They build such physical assets as facilities and equipment to create competitive advantages. They produce tangible goods such as cars, machines, refrigerators, and food products. Their business models are created around fixed assets, working capital, and economies of scale. They derive strength from mass production, offering the same products at lower and lower prices. Examples include Ford, GE, GM, Johnson & Johnson, and other "brick-and-mortar" companies.

Shareholders own the company's equity. All physical assets are readily fenced in and chained down so that company management can exert full control over these important assets that serve as the basis of the company's competitiveness in the marketplace.

Companies deploy in-house capabilities. Major functions are vertically integrated, starting from raw materials, work in progress, finished goods, distribution, marketing, and sales, and ending with support service to customers. The emphasis is on self-sufficiency, stability, and incremental growth.

These companies create intensive rivalries with competitors to motivate employees and to ensure success in the marketplace. Companies are run as "going concerns," intended to last forever.

In old economy companies, innovative ideas typically float up the chain of command to be screened and reshaped for further evaluation before finally being presented for decision-making and possible implementation sometime in the future. Decision-making is resource centered. Resource centering is the optimum use of limited resources available to the company.

These companies maintain a staff to process order entry, invoicing, accounts receivable, accounts payable, procurement, shipping, delivery, and other functions. Such processes take time and cost money. Also, internal financial performance reports are typically prepared on a monthly basis.

14.3.2 Knowledge Economy Companies

Knowledge economy companies center on a small number of core operations. They have a permanent staff to advance technologies, but they assume a predominantly web-like organizational design that links business partners, employees, external contractors, suppliers, and customers in various collaborative arrangements. All participants in the networked arrangements grow interdependently. The networks remain flexible, and the business and activity boundaries of the companies are vague and fluid. Knowledge-economy companies aim to achieve future growth by way of networked partnerships (Lefebvre et al. 2013).

These companies are idea intensive, as ideas are the key assets in a knowledge-based economy. The assets are in employees' heads, not physically constructed on the ground. They provide digitizable goods and services (e.g., data, software, books, news, music, movies, games, financial services, and advertising). Knowledge economy companies also e-transform themselves to produce commodity-type goods (e.g., jeans, cosmetics, computers, clothing, and sneakers). Their business strategies emphasize cost reduction by applying technologies secured through networks, and they bring breakthrough ideas to their markets first.

They derive strength from mass customization, wherein customers are given tools to design individually preferred products. Excellent examples include the following:

1. Dell offers custom-designed computer systems from a group of well-defined system components (memory size, hard-drive capabilities, modem type, monitor, etc.) with price and delivery options.
2. Levi's presents custom-designed Spin jeans for special fit, style, and color, with 1.7 million variations to choose from.
3. Procter & Gamble (P&G) offers custom-designed cosmetics and perfumes with up to 50,000 different choices.
4. Nike customizes sneakers by features, styles, and colors.
5. American Quantum Cycles custom-designs motorcycles that use different seats, handlebars, and paint colors.
6. Charles Schwab's mutual funds screener allows customers to design their own investment portfolios.
7. Mattel's My Design Barbie lets customers build a friend for Barbie by choosing hairstyle, color, complexion, and eye color for a doll.
8. Cisco's Marketplace allows business customers to create routers, switches, and hubs to build specific computer hardware systems.
9. Point.com's Service Plan Locator allows customers to choose wireless phones, service plans, and accessories.

Such choice boards allow companies to first sell and then produce, instead of the former way of spending money to create products and services, hoping to eventually sell some or all of them. These companies have high price-to-book (P/B) value ratios and high per-employee market values. For example, Microsoft employed 31,000 people at one time and has a market value of $600 billion. Yahoo has a P/B ratio of 40. Other such high-performing companies include Apple, Google and Amazon.

Shareholders of these companies do not have true ownership of the intellectual property assets, as ideas reside within the employees' heads and cannot be controlled. Because of workforce mobility, this is a significant risk factor for knowledge economy companies.

Typically, knowledge economy companies build their core competencies, outsource the rest, and are virtually integrated. They nurture an array of formal and informal networks of partnerships and alliances consisting of free agents, outside contractors, designers, prototype producers, manufacturers and distributors, and others. As partnerships and alliances shift, these networks change accordingly. They focus on achieving advantages in technology and in time to market in order to realize outstanding growths.

By outsourcing noncore activities (manufacturing, product design, accounting, procurement, customer services, janitorial services, and others), companies save time and management attention, if not money, to go after big opportunities of the e-future. Well-known examples include the following companies:

- Cisco Systems, the most networked organization, with all administrative functions conducted over the Internet, owns only 2 of 34 plants that make its products, and 90% of the company's orders are not handled by human hands.
- Dell manages the most efficient supply chain network, maintaining an inventory for six days only.
- General Motors created a "sensing and responding" supply chain for delivering customized vehicles in 10–12 days in 2003–2004.

Sometimes companies collaborate even with competitors to achieve win–win solutions. For example, Covisint is an electronic trading exchange created collaboratively by several automakers, namely, GM, Ford, DaimlerChrysler and Renault-Nissan, to streamline parts procurement and generate revenue.

Excellent ideas are instantly transmitted through the web-like organizational networks. Empowered employees make decisions that center on creating competitive advantages through shortened time to market and better customer satisfaction, which will bring about an increase in top line. Companies achieve "virtual financial close" as the processes of order entry, invoicing, shipping, accounts receivable, accounts payable, procurement, and others are digitized to function seamlessly, making all financial performance data only "one click away." Massive digitization allows companies to remove people from various routine assignments and thus achieve advantages in cost, speed, and quality of information.

In the United States, interaction costs, which are the expenses incurred to get different people and companies to work together to create and sell products/services, account for about 50% of all labor costs. Because these interactions are automated in knowledge-economy companies, their initial productivity gains are predicted to reach 20%–40% per year. These companies embrace digitization through the deployment of suitable enterprise integration software systems. Specific examples of unit cost reduction strategies include the following:

1. *Bank transactions*: A transaction by a bank teller costs $1.25, compared with 54 cents by phone, 24 cents by ATM, and 2 cents by the Internet.
2. *Procurement*: This costs $140 for people to procure parts and supplies, compared with $11.70 with an Internet-based catalog system (Corning, for example).
3. *Handling job applicants and resumes:* This costs $128 for a people-based procedure, but only 6 cents when accomplished by digitizing the process and eliminating manual labor.
4. *Customer inquiry processing:* This costs $50 over the phone, compared with 50 cents with the Internet (General Electric, for example).

The key is to make Internet use a strategic priority. Spotting opportunities early and exploiting them fast will work. Knowledge economy companies regard human skills, expertise, and relationships as the most precious resources in an organization, whereas the twentieth-century "brick-and-mortar" companies emphasize physical assets of production.

14.4 Characteristics of Progressive Companies

Progressive companies are those knowledge economy companies which make it a strategic priority to utilize Internet-based technologies, invent innovative business models, create supply chain networks, empower a diversified workforce, and pursue customer satisfaction in order to achieve business success in the marketplace.

The major trends discussed in Section 14.3 tend to shape the progressive companies of the new millennium. These companies look for real-time customer feedback (e.g., via online chat rooms) to get customers to talk about performance and problems. They focus on a market segment of one, delivering mass-customized products and services. They induce loyalty by managing the customer relationship well. They view the enduring relationship with employees as an enormous asset, because these employees connect the company to its partners. Their total workforce consists of permanent staff, temporary service people, contract workers, free agents, and consultants. The companies are further linked to the employees of their networked partners. Like actors and athletes, talented businesspeople will have agents to represent them.

A case in point is Nokia, a cell phone giant in Europe. The company entered the U.S. market successfully with only five permanent employees by outsourcing sales, marketing, logistics, and technical support. Nokia employees work with a mix of contract teammates from around the globe, many of whom they never meet face to face. Every project calls for a new team composed of people with special talents and skills. In such a dynamic setting, information that is more than one hour old will be viewed with skepticism. Everyone's performance is carefully and constantly evaluated. If there is no contribution, there will be no continued membership.

Progressive companies streamline most staff jobs by employing certain types of enterprise-planning systems. They devote special attention to supply chain management, enterprise integration, customer relations, knowledge management, web-enabled transactions, and globalization.

Companies in the new millennium must manage all stakeholders well in order to succeed in the marketplace. They take care of all five categories of stakeholders: (1) *Investors* are needed for capital to grow. (2) *Customers* provide the sources of sales revenue growth and earning stability. (3) *Employees* provide productivity and client satisfaction. (4) *Suppliers* provide competitive advantages in technology, innovation, and supply chain management. (5) *Communities* influence the company's reputation, as well as local regulations, and legislation that the company must manage. Some of the unique characteristics of these companies are described next.

14.4.1 Complex Organizational Design

The organizational form of progressive companies may be large and complex. They have less mass, as various in-house functions are performed by alliances, joint ventures, and partners in networks, and they tend to constantly shift portfolios of businesses and assets. The new trends discussed in this chapter reflect the competitive needs for operational efficiency and customer focus. The drive for efficiency and a customer-centered corporate strategy is enabled by available technologies.

A traditional value chain is typically driven by core competencies (as depicted by the flowchart in Figure 14.1), starting from what the companies can do best and then defining products and services that the customers may want.

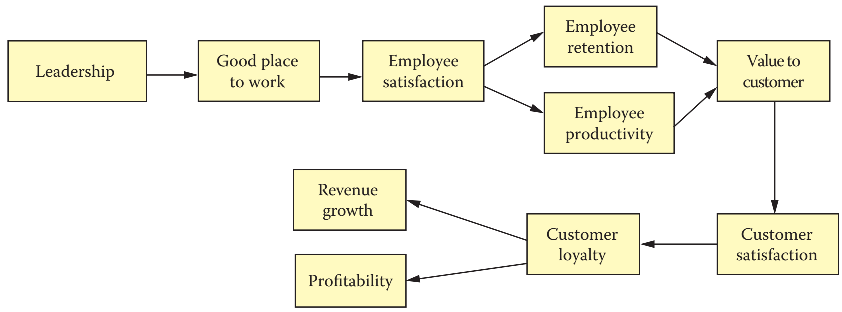

FIGURE 14.1
Traditional value chain.

A reverse-value chain begins with customer needs (defined by extensive customer study and market research) and works backward along the fulfillment chain into company capabilities and functions (see Figure 14.2).

Enterprises organized according to the reverse-value chain tend to be more capable of satisfying the needs of customers, a key requirement for business success in the twenty-first century (Hines 2000).

Another guideline useful for organizational design is to choose a narrow focus. Few organizations can do many things well; none shine in every dimension of business, such as cost, quality, price, convenience, and ease of use. Examples of a narrow focus in business include service, operation, and innovation. *Service excellence* focuses on strong CRM that anticipates customers' needs, enables self-service, and offers value. *Operational excellence* stresses the optimal leverage of assets, efficient transactions, customized solutions (sales intelligence, management of customers' expectations), the use of measurement systems, outsourcing noncore processes, end-to-end process effectiveness, and others. *Continuous innovation excellence* exhibits product leadership to delight customers, grows by merger and acquisitions, proactively educates customers about how to use and benefit from new products, and encourages innovation.

A progressive enterprise must link three major groups of stakeholders together: (a) customers, (b) back-office workers, and (c) supply chain partners. After these groups of stakeholders are properly linked together, the design of a progressive enterprise organization may contain major units, as illustrated in Figure 14.3.

14.4.2 Global Reach

Progressive companies serve global markets by increasing product specifications and otherwise offering products that differ from those in the domestic markets. They also derive more revenues from overseas markets than domestic markets and have future growth opportunities weighted toward emerging markets.

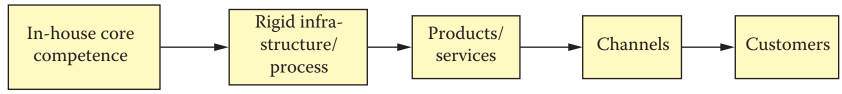

FIGURE 14.2
Reverse-value chain.

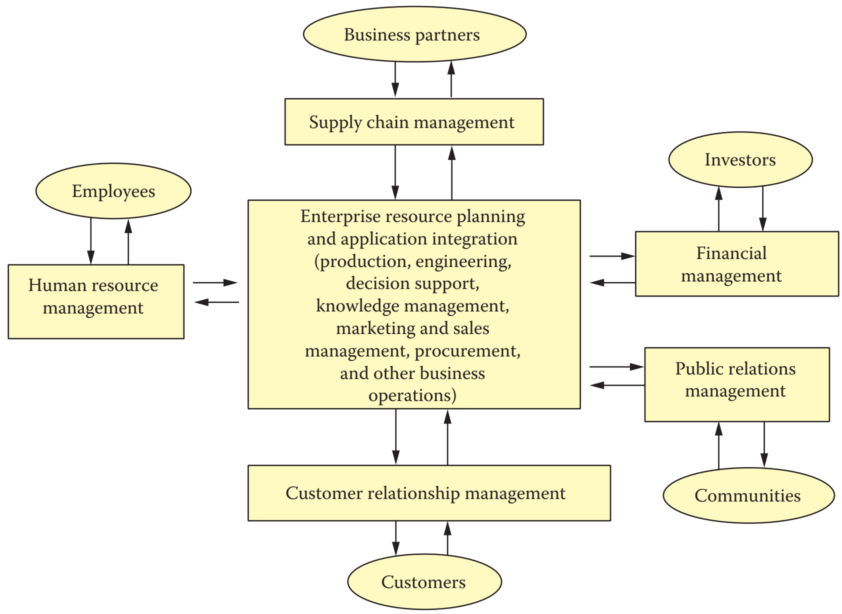

FIGURE 14.3
Organizational units in progressive enterprises.

14.4.3 Partnerships

Progressive companies are dynamic. They constantly create external networks to access product innovation, process technologies, manage working capital, maintain market access, and cultivate knowledge. These critical linkages are based on mutual benefit, trust, empathy, and good communication—and they are vigorously protected (Siegel et al. 2003).

14.4.4 New Composition of Employees

The full-time regular employees in progressive companies are technically literate; they embody the core competencies of these companies. Some of these employees may reside abroad, have modern attitudes toward the employer–employee relationship, and change jobs frequently, preferring opportunities for interesting and challenging work that stretches their abilities.

Supporting these core employees are various part-timers, independent contractors, agency temporaries, and employees of vendors and consultants who will also be engaged. Therefore, the company may have a smaller share of support staff provided by outside agencies.

Example 14.1

What are some new characteristics of workers in the twenty-first century?

Answer 14.1

Workers in the new century may have these characteristics:

1. Free agents can now sell their skills around the world via the Internet; this was impossible to do not too long ago.

2. Professional groups are likely to offer the senses of identity and community, health insurance, and other benefits needed by free agents who move from one company to another.
3. Each employee may have as many as 20 different jobs throughout a career of 45 years (an average of 2.5 years per job). They tend to constantly bargain for better deals within their organizations (e.g., stock options, a sign-up bonus, new projects, Thursdays off, an August sabbatical).
4. Workers seek to acquire a broad set of marketable skills, as companies will continue to outsource white-collar jobs and spread centers of excellence around the world to seek advantages in cost, speed, and expertise.
5. STEM professionals and leaders need to be flexible and adaptable to organizational changes and become cosmopolitan, equally at ease both at home and abroad.

14.4.5 Management Reporting Layers

Progressive companies will have fewer reporting layers between business units, divisions, and executive management. Business units will increasingly operate autonomously and be measured by specific performance metrics (e.g., a balanced scorecard).

14.4.6 Customer Sophistication and Demand

In the new millennium, customers will be better informed, more sophisticated, and increasingly demanding. They will use the Internet to access information, demand product customization, require price transparency, and conduct comparison shopping. Customer satisfaction will hinge on product/service features and quality, and after-sales support and services. More data on customer satisfaction will be published on the web, exposing the market leaders and followers in every industry. Progressive companies focus on serving their customers well.

14.4.7 Brand Image

Because a good public image is regarded as a competitive advantage, progressive companies nurture a positive reputation of being reliable and ethical. Brand image is expected to become increasingly important to the stakeholders of all companies.

Progressive companies strive to protect public interests from ill-conceived mergers and acquisitions, dangerous operating practices, antisocial business decisions, and oligopolistic behaviors. Governments are known to have taken decisive actions against some violators in the past, for example: (1) Alaska opposed BP Amoco's acquisition of ARCO to take a 70% share of Alaska's oil and gas reserves; (2) Italy accused Coke of distorting competition rules; (3) the U.S. Department of Justice (DOJ) raised issues with Microsoft's monopoly of the Windows operating system market; and (4) the U.S. DOJ approved the merger of AOL and Time Warner only after having studied it for more than one year.

14.4.8 Stock Market Valuation

The stock valuation of progressive companies will be based on returns on their intangible assets instead of their tangible ones. The intangible assets of a company include (a) brand capital (customers and the community) and (b) knowledge capital (strategic suppliers and employees). Progressive companies are capable of optimizing the return on these intangible assets that form the primary basis for the companies' competitiveness in the marketplace.

14.5 Transition to the Knowledge Economy

Numerous old economy companies need to modify their business practices in order to become successful in the knowledge economy (Lefebvre et al. 2013).

For companies to succeed in the new millennium, several corporate values are critical. *Speed* is important, as time may be more valuable than money. Companies looking for speed may favor the strategy of buying over building. *Talents* are crucial, as companies compete largely on the capabilities of attracting the best people, empowering them to innovate, and creating an environment that makes the best people want to stay. *Market dominance* refers to the company's emphasis on long-term market position rather than quarter-to-quarter increments in performance. *Customer orientation* signals the value placed by the company on tracking the needs of customers and creating supply chains to quickly and reliably satisfy them. *Efficiency* is a critical corporate value: companies streamline operations using advanced software technologies, such as enterprise integration systems, to adapt to a changing marketplace. Finally, *outsourcing* represents a preference for the company to farm out noncore activities in order to conserve resources, time, and management attention.

Outsourcing cuts down on a company's investment, shortens it's time to market, and enables it to take advantage of the unique skills and expertise of the supply partners in the production of products and services. For example, Cisco Systems is known to have dropped in-house R&D in favor of buying start-up companies for its technological needs. Companies need to aggressively engage partnerships, form supply alliances, and create networks with domestic and international suppliers of raw materials, subassemblies, semifinished goods, and others to flexibly and speedily make finished products. Outsourcing facilitates mass customization by which product features are steadily modified to meet customers' needs. The major issues involved in outsourcing and in the management of supply chain networks are addressed next (McGrath and Hoole 1992; Venkatesan 1992).

14.5.1 Product Design and Specification

Managers need to communicate and enforce interface specifications of all parts manufactured by the partners. Standardizing interfaces to promote exchangeability of parts and create varying product features is essential. Effective infrastructure hardware and software systems will facilitate supply chain management. Companies also need to integrate middleware, electronic data interchange, systems technologies, regulations, production practices, and other elements of their business.

Reducing the number of global component suppliers may be accomplished by minimizing the number of components in products. Designing each component innovatively by the use of common components minimizes reengineering to meet local needs. The company should strive to exceed local quality requirements to create a competitive advantage.

14.5.2 Manufacturing

Managers should take the following actions: (1) selectively utilize web-based manufacturing and operations enablers to attain business advantages; (2) make critical parts in-house and combine with vendor-supplied parts to assemble the finished products; (3) specify assembly procedures to ensure product integrity; (4) conduct a statistical process control (SPC) to ensure system quality of the assembled finished products; and (5) pursue International Organization for Standardization (ISO) and other quality process certifications.

Linking design with manufacturing allows production costs to move down the learning curve. Successful companies produce high-labor-content parts in low-labor-cost areas and use skilled labor for other high-technology components. The assembly of finished products in plants close to local markets ensures response to local content laws, import duties, final tests, and quality control. Transferring components to assembly plants and shifting like components from plant to plant balances the load among regions.

14.5.3 Management

Companies need to (1) share information and collaborate with networked global partners; (2) preserve corporate knowledge and ensure global application and learning; (3) set up a CRM system by tapping into the expertise, innovation, and knowledge base of the networked partnership; (4) assist in implementing an ERP system to optimize the utilization of corporate assets; and (5) make the production process transparent to be traceable by customers.

STEM professionals and leaders may be particularly qualified to facilitate the transitions of old economy companies into knowledge economy companies. Companies of the twenty-first century will form more external relationships with networked suppliers, key customer groups, or client companies for which products or services are made on contract. The uniqueness of these relationships can be attributed to their characteristics:

- *Transience*: A contractual relationship may last for a short period of time, until the market conditions call for change.
- *Diversity*: Partners may be global, with varying degrees of differences in culture, language, working norms, and value systems.
- *Coordination*: Strong coordination capabilities are needed, along with project management skills, to handle human relations, risk management, conflict resolution, tolerance for uncertainty, problem solving, motivation capabilities, and communication.

Managers also need to spend increasing amounts of time nurturing external relationships.

14.5.4 Various Other Issues

There are additional issues that need to be addressed properly. Managers must ensure just-in-time (JIT) delivery and optimize transportation logistics. Balancing loads between global sites will enable the company to adjust to changing supply and demand and marketplace conditions. The company must proactively respond to labor, political, currency, and other unexpected changes and conflicts. Procuring almost all parts centrally, except low-cost and low-volume items, helps the company to realize economies of scale. Vendors are to be centrally qualified. The company needs to coordinate marketing and sales forecasts centrally for global markets, on the basis of local inputs.

Example 14.2

Companies in the future will rely more and more on temporary workers, specialized vendors, and consultants to flexibly address unique needs and contingencies. Employer–employee relations will become peer-to-peer relations rather than the hierarchical ones. STEM professionals will find that their careers are less stable than in previous generations.

In your opinion, what is the most important thing that STEM professionals and leaders can do to prepare for this volatile, uncertain, and dynamic scenario?

Answer 14.2

STEM professionals and leaders need to proactively manage their own careers more closely than ever before, while keeping their skills, knowledge, and experience marketable. A good way to focus is to pursue lifetime learning about the changes in technologies, tools, industry, and business. Those STEM professionals who do not take care of their own careers will rapidly become redundant.

The employer's position is well stated by Bahrami (1992): "You own your own career, we provide you with opportunity!"

14.6 Personal Strategies for the Future

STEM professionals and leaders need to personally ready themselves to meet challenges in the future related to the application of Internet-based technologies and the extension of market reach and globalization (Stettner 2013; Kamp 2012). To acquire the skills to be successful in the future (Chang, 2016), they should:

1. Get postgraduate education, which will be increasingly essential to achieving personal prosperity in the future. Learn how to learn quickly. Constantly hone skills and acquire broader perspectives.
2. Become efficient in digesting vast amounts of information, measuring trade-offs, and making the right choices. Be computer and Internet literate, develop conceptualization skills, and acquire fast reading and knowledge-processing capabilities.
3. Acquire a good understanding of new products and markets in transition, which are often defined by ever-changing technologies.
4. Be a capable communicator, compromiser, and leader of change.
5. Foster external relationships and networks of partners to succeed. The number and complexity of partnerships are expected to increase.
6. Lead with suitable style. Visualize yourself as the director of a symphony orchestra or ballet company. The leader sets the vision, but allows the individual "artists" to perform, and to fashion their own roles in the performance. The key ability is to be assertive and ultimately emerge with a common direction to which everyone becomes committed.

7. Supervise temporary employees, outside contractors, and other service providers. The number of permanent employees will decline and the number of transient workers will increase.
8. Become familiar with the capital market, as leaders will spend more and more time attracting venture capital. Skills to communicate with analysts and investors are important.
9. Prepare for intensive enterprise integration due to globalization. Exercise "pattern recognition" to spot trends that may affect the company's future.
10. Acquire the following minimum survival skills for twenty-first century office workers:
    a. Be good at something the world values. Keep up marketable skills to offer value above and beyond what others can offer elsewhere. These skills include:
        i Leadership—technology planning, management of diversified employees, and perspectives with global orientation are essential.
        ii Technologies—include core, emerging, and innovative. There must be a love of technology present. Since technology changes everything, embracing it is essential.
    b. Stay away from service technologies that are readily outsourced. These include software programming, procedure or manual preparation, basic design assignments, customer support, product testing, experiments, statistical studies and analyses, and other rudimentary engineering/technology jobs.
    c. Also, stay away from those company functions that are being taken over by enterprise integration software systems (e.g., Oracle, Ariba, I2, and Baan). Understand clearly what these software systems can do, and then focus your efforts on acquiring skills for the high-level work that such software systems cannot perform.
11. Create networks. Whom do you know? What do others know that you can use? It is extremely important to link with future project mates and peers who appreciate your talents and capabilities. Determine whom you can call on to further your current and future projects and goals.
12. Nurture an entrepreneurial instinct. Seize opportunities for new projects and act on them.
13. Do marketing, as suggested by a popular slogan:. "Early to bed, early to rise, work like in hell, advertise!" Tell your story to let people know more about you; have a personal website; attend trade show presentations.
14. Grow better constantly. Manifest a passion for renewal.
15. Prepare oneself to acquire a broad-based background in design, engineering, marketing, and finance in order to inform better decision-making.

14.7 Contributions in the New Millennium

Significant changes are anticipated as a result of the transformation of old economy (vertical) companies to knowledge-economy (virtual) companies.

Knowledge economy companies rely more on innovations, brand, customers, and unique knowledge to compete and less on hard assets, such as the plants, equipment, real estate, and traditional distribution channels of the old economy companies. STEM professionals and leaders will play an increasingly important role in the new millennium.

14.7.1 Technologies

Applying technological intuition to lead in business planning involves the deployment of emerging technologies (Spencer and Johnston 2002; Brown and Heller 2003). STEM professionals and leaders are particularly qualified to constantly track the development of emerging technologies and actively screen them to allow for possible adoption for in-house use.

Example 14.3

Continuous improvement is a critical requirement for all companies. How can the process of continuous improvement be implemented in the new millennium?

Answer 14.3

Continuous improvement helps companies to remain competitive in the marketplace. To manage the continuous improvement process, company management should do the following:

1. Specify objectives in consultation with top management. Assign the responsibility of managing the continuous improvement process to someone with visibility. Commit resources and establish a central office to coordinate the continuous improvement efforts. The mission of this office must be communicated to all employees.
2. Define specific goals in a number of areas, on the basis of inputs from various divisions, using standards derived by gleaning the available best practices in the industry.
3. Create a number of task forces by interviewing and selecting capable and devoted people who have expertise in diversified disciplines. Each task force should be empowered to pursue improvement ideas in a specified domain.
4. Hold teamwork training sessions for members of diversified cultural and technical backgrounds. Visit team members in various locations to establish contact, assure understanding, and build trust.
5. Set up a communications system (e.g., an intranet, videoconferences, regional meetings, and phone, fax, or multimedia technologies) to enable members to interact constantly. Apply web-based tools to foster close collaboration.
6. Create "suggestion box systems" at each site for members to solicit and obtain inputs from knowledgeable employees. All employees are encouraged to contribute new ideas for optional improvement.
7. Empower the task-force teams to implement improvement ideas deemed useful and to apply resources made available from a central continuous improvement office.
8. Reward employees who suggested those creative ideas that produced positive results after implementation. Present awards in well-advertised meetings to promote the continuous improvement effort. Publish awards and the positive results in company newsletters and other suitable media to practice positive reinforcement.
9. Encourage the cross-pollination of ideas from all employees at various locations to take advantage of their diversified experience and viewpoints.
10. Summarize and publicize possible results on a regular basis.

14.7.2 Innovations

Applying innovations to shorten product development cycles, reduce time to market, cut costs, and add features will create competitive advantages (Deschamps and Nelson 2014). Companies create new businesses by following a typical six-step process, (see Chapter 10).

1. Define and develop core technologies to solidify company strengths (best practices, continuous improvement). Core technologies represent the foundation for corporate partnerships and alliances.
2. Create products and services built around core technologies to differentiate from others and to succeed in the marketplace.
3. Validate market acceptance of proposed product and service concepts.
4. Conduct technical feasibility tests to produce and deliver the proposed product or service. Focus on networked partner supply chains, distribution logistics, sales, and services.
5. Raise capital by selling company stocks or from venture funding.
6. Implement the approved business plan by systematically using improved best practices.

It is noteworthy that four of the six steps listed in this section need significant innovative inputs from STEM professionals and leaders. Creating strategic differentiation needs to become a high-priority activity for them to add value.

14.7.3 Value Addition to E-Transitions

STEM professionals and leaders should seek to apply web-based technologies to improve efficiency; develop mass customization ("build-to-order") systems—using design, production, logistics, and service—to strengthen corporate competitiveness; and transform other corporate functions to add business values. Creating operational excellence should also be a high-priority activity with which to add value.

14.7.4 Customer and Knowledge

The management of customers, knowledge, and connections is of critical importance. STEM professionals should contribute in the following areas:

1. *Relationship management*: CRM involves analyzing data generated by call centers and other sources and devising programs to foster relationships with customers.
2. *Connectivity creation*: Connectivity development, maintenance between business partners (e.g., suppliers, alliance partners, employees, and customers), and content management (e.g., software selection, hardware specification, system design, interface design, quality assurance, and control of proprietary information) are essential.
3. *Knowledge management*: STEM professionals are reminded that "It is not who you know. It is what who you know knows." How can your knowledge and theirs be combined to create new win–win opportunities?

14.7.5 Social Responsibility and Leadership

STEM professionals and leaders should become visible leaders in society by speaking out more forcefully on broad issues of social interest on behalf of their companies and professional associations. Examples of such broad issues include

1. Ethics and integrity of business and leadership
2. Environmentally friendly corporate policies to combat global warming
3. Globalization and the environment
4. National energy policies that focus on conservation or exploration
5. The question of taxation on the Internet
6. The patient's bill of rights in dealing with health maintenance organizations (HMOs)
7. Investment of social security benefits by individuals

Example 14.4

In the new millennium, STEM professionals and leaders will need to be prepared to lead and manage technology-intensive companies and industries. What specific technology management activities should they be concerned with?

Answer 14.4

Generally speaking, there are eight activities that STEM professionals and leaders should pay attention to (Thamhain 2005):

1. Integrating technology into the overall strategic objectives of the firm (strategic planning)
2. Getting into and out of technologies effectually (gatekeeping)
3. Assessing and evaluating technology more effectively (making decisions and choices)
4. Conceiving better methods for transferring and assimilating new technology (managing technical knowledge)
5. Reducing new product development time (creating supply chains and applying innovations)
6. Managing large, complex, and interdisciplinary or interorganizational projects, programs, and systems (leading cross-functional or global teams)
7. Managing the organization's internal use of technology (leading teams and managing projects)
8. Leveraging the effectiveness of technical professionals (managing knowledge workers)

STEM professionals and leaders should focus not only on R&D management or management of technical professionals, but also on managing manufacturing and process technology, new product development, and other technology-intensive functions in an organization. In addition, they strive to implement projects and programs correctly the first time and dedicate their efforts to continuous improvement. They are capable of commercializing technology products because they possess the required background and training in activity-based costing (cost accounting), net present value (NPV) analysis (financial management), and customer relations management (marketing management). The critical roles of STEM professionals and leaders are well recognized, as technology is of strategic importance to any profit-seeking enterprises.

14.8 The Challenges Ahead

This book is aimed at assisting STEM professionals and leaders in assuming leadership positions in enterprises of the twenty-first century. Many of these enterprises are affected by rapid changes in technology and the fast-paced advancement of globalization. Anonymous (2012) reviewed various future scenarios for the next 15–20 years and offered the following foresights:

1. By 2030, there will be a shift of economic power (e.g., measured in gross domestic product [GDP]) from the United States, Europe, and Japan to China, India, and Brazil. By 2025, China alone will contribute about one-third of global economic growth.
2. The world will have a total population of 8.3 billion people (2030), from 7.1 billion (2012), including a major growth in the global middle class, especially in the East.
3. The projected changes in population include: (a) aging, (b) shrinking number of youthful societies and states, (c) migration of workers, and (4) urbanization of the population.

In combination, these scenarios suggest that there will be an increased demand for services as related to health care, professional advisement, retail trade, leisure and hospitality, governmental services, transportation, education, financial activities, information services, and others in the global marketplace. STEM professionals would have to be under a rock to not know that we are in a global economic growth period. The key challenges for existing service enterprises would then be how they could make use of the currently available technologies to preferentially participate in these new growth markets, while fully taking into account the local cultural norms and customs. STEM professionals should have the wherewithal to help meet these critical challenges.

The pathways outlined in this book to periodically introduce novel product/service packages in order to create strategic differentiation in the marketplace and employ productivity-enhancing tools to achieve operational excellence in all work processes should allow all enterprises engaged in global markets to stand out.

The first section of the book consists of the basic functions of engineering management, such as planning (Chapter 2), organizing (Chapter 3), leading (Chapter 4), and controlling (Chapter 5). These functions provide STEM professionals and leaders with foundation skills to manage themselves, staff, teams, projects, technologies, and global issues of importance.

Best practices are emphasized as the pertinent standards for goal setting and performance measurement. STEM professionals and leaders solve problems and minimize conflicts to achieve the company's objectives. They use the Rational method to make decisions and take lawful and ethical actions. They engage Monte Carlo methods to assess projects involving risks and uncertainties. They apply emerging technologies, motivate a professional workforce of diversified backgrounds, develop new generations of products and services in a timely manner, and constantly surpass the best practices in industry.

The roles of STEM professionals and leaders in strategic planning, employee selection, team building, delegating, decision-making, and managing creativity and innovation are explained. The augmentation of managerial competencies is emphasized.

The second section of the book covers the fundamentals of business, including cost accounting (Chapter 6), financial accounting and analysis (Chapter 7), and marketing management (Chapter 8). This section is written to enable STEM professionals and leaders to acquire a broadened perspective of the company business and its stakeholders and to facilitate their interactions with peer groups and units.

These chapters also prepare STEM professionals and leaders to make decisions related to cost, finance, products, service, and capital budgets. Discount cash flow and internal rate of return (IRR) analyses are reviewed. These discussions are of critical importance, as decisions made during the product design phase typically determine up to 85% of the final costs of products. Additional discussions are presented of activity-based costing (ABC), to define indirect costs related to products and services, and of economic value added (EVA), which determines the real profitability of an enterprise above and beyond the cost of capital deployed.

Also presented is capital formation through equity and debt financing. Resource allocation concepts for assets in place and option pricing for capital investment opportunities are addressed as well. By understanding the project evaluation criteria and the tools of financial analyses, STEM professionals and leaders will be in a better position to secure project approvals. A critical step to refining technological projects is the acquisition and incorporation of customer feedback. For STEM professionals and leaders to lead, they must meet the major challenges that arise from the initiation, development, and implementation of major technological projects, which contribute to the long-term profitability of the company.

The important roles and responsibilities of marketing in any profit-seeking enterprise are then introduced, along with the supporting contributions expected of STEM professionals and leaders. Various progressive enterprises are increasingly concentrating on CRM to grow their businesses. This customer orientation is expected to continue to serve as a key driving force for product design, project management, plant operation, manufacturing, customer service, and countless other engineering-centered activities.

The third section of the book addresses six major topics: engineers as managers and leaders (Chapter 9), creativity and innovation (Chapter 10), ethics in engineering and business management (Chapter 11), operational excellence (Chapter 12), globalization (Chapter 13), and engineering management in the new millennium (Chapter 14). These discussions provide additional building blocks to enhance the preparation that STEM professionals and leaders must undertake to assume technology leadership positions and to meet the challenges in the new millennium.

Figure 14.4 illustrates the 12 building blocks, covered by this book, which establish the solid foundation of new engineering management leadership.

STEM professionals are known to possess strong skill sets that enable them to do extraordinarily well in certain types of managerial work. However, some of them may also exhibit weaknesses that prevent them from becoming effective leaders in engineering organizations. The expected norms of effective leaders are described. Steps enabling STEM professionals and leaders to augment their leadership qualities and attune themselves to value-centered business acumen are elaborated. Certain outlined steps should be of great value to those who want to become better prepared for creating new products or services based on technology, integrating technology into their organizations, and leading technology-based organizations.

A number of tried-and-true rules are included to serve as suitable guidelines for STEM professionals and leaders to become excellent leaders. Above all, they are expected to lead with a vision of how to apply company core competencies to create value, insights into

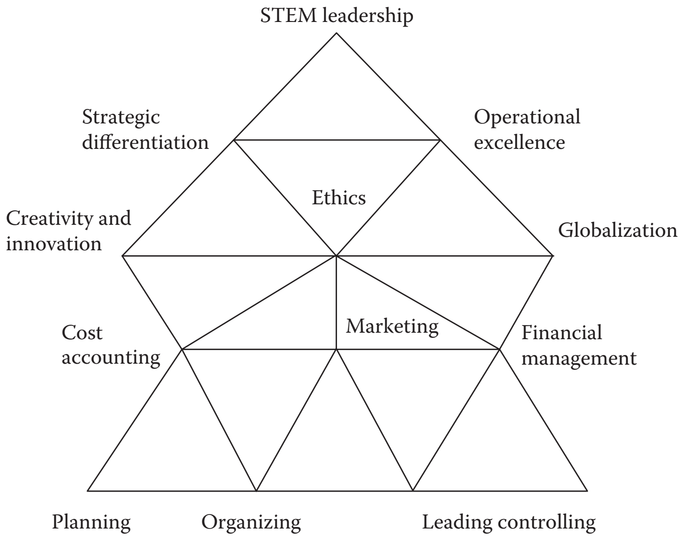

FIGURE 14.4
Three-decker leadership architecture.

how to seize opportunities offered by emerging technologies, and innovations in making products and services better, faster, and cheaper, so that they constantly improve customer satisfaction. The concepts of value addition, customer focus, time to market, mass customization, supply chains, enterprise resources integration, and others are also elucidated.

Although STEM professionals and leaders are already known to be ranked highly in trustworthiness and integrity (ahead of businessmen, bankers, certified public accountants, politicians, lawyers, and others), it is important for all STEM professionals and leaders to remain vigilant in observing a code of ethics. Other topics related to ethics are discussed, with examples of several difficult ethical dilemmas.

The changes wrought by the Internet are transforming most aspects of company business, including information dissemination, product distribution, and customer service. As computer processor design, software development, and transmission hardware technologies continue to advance, their roles in business will surely grow steadily and affect various functions of engineering management in the future. STEM professionals and leaders need to know which web-based enablers for engineering and management are currently available. They must identify which ones can be applied effectually to promote product customization, expedite new products to market, align supply chains, optimize inventory, foster team creativity and innovation, and enhance customer service. Presented in considerable length is a comprehensive set of web-based tools (Chapter 12) related to product design, manufacturing, project management, procurement, plant operations, knowledge management, and supply chain management.

Globalization expands the perspectives of STEM professionals and leaders further with respect to divergence in culture, business practices, and value. Globalization is a major business trend that will affect innumerable enterprises in the coming decades. STEM professionals and leaders must become sensitized to the issues involved and prepare themselves to help their companies in seizing the new business opportunities offered in the emerging global markets. They need to be aware of the potential effects of job migration caused by globalization and take steps to prepare themselves to meet such challenges. A major hurdle for STEM professionals and leaders to overcome is to create global technical alliances in order to take advantage of new technological and business opportunities.

Engineering management will face external challenges in the new millennium. What these specific challenges are, how STEM professionals and leaders need to prepare to meet these challenges, and how to make optimal use of location-specific opportunities to create competitive advantages have been examined. Progressive companies change organizational structures, set up supply chains, expedite e-transformation, and implement advanced tools to serve customers better, cheaper, and faster.

Globalization is also expected to constantly evolve. The United Nations has predicted that, by the year 2020, three of the five biggest national economies will be located in Asia. There will certainly be winners and losers as businesses become more and more global. It is important for STEM professionals and future leaders to explore prudent corporate strategies for engineering enterprises in the pursuit of globalization, while minimizing any detrimental impact on the environment, protecting human rights and safeguarding proper labor conditions.

As graphically displayed in Figure 14.4, these twelve skill sets enable the formation of STEM professionals' leadership. What is still required for STEM professionals and leaders to actively practice these knowledge sets in order to add value? When exercising leadership, Zenger et al. (2002) suggest that close attention be paid to the following "Leadership" model:

L – *Listening*, leveraging own capabilities and strengths. Confucius said: "When walking with two other people, one of them could surely be my teacher."

E – *Empowering,* entrusting people, and enthusiasm. Winston Churchill said: "Success consists of going from failure to failure without loss of enthusiasm."

A – *Action driven*, attitudes, accountability, and ability to motivate others. David Starr Jordon said: "Wisdom is knowing what to do next, virtue is doing it."

D – *Determination*, decisiveness in setting directions. Patty Hansen said, "You create your opportunities by asking for them."

E – *Energy,* empathy, effectiveness and efficiency. Benjamin Franklin said, "Energy and persistence conquer all things."

R – *Rewarding,* respecting, risk taking and reinventing self. Williams James said, "The deepest principle in human nature is the craving to be appreciated."

S – *Setting personal examples*, servicing people, and showing vision. George Bernard Shaw said, "Imagination is the beginning of creation. You imagine what you desire, you will what you imagine and at last you create what you will."

H – *Honesty and honorable objectives*. Henry Clay said, "Of all the properties which belong to an honorable man, not one is so highly priced as that of character."

I – *Innovative, integrity*, interpersonal skills, and inspiring capabilities. Albert Einstein said: "Discovery consists of seeing what everybody has seen and thinking what nobody had thought."

P – *Persistence,* positive outlook, and proactive communications. Thomas Edison said: "Genius is 1% inspiration, 99 % perspiration."

STEM professionals and leaders are expected to burnish their leadership credentials and bring their deep knowledge, experience, and wisdom to bear in helping to focus on the

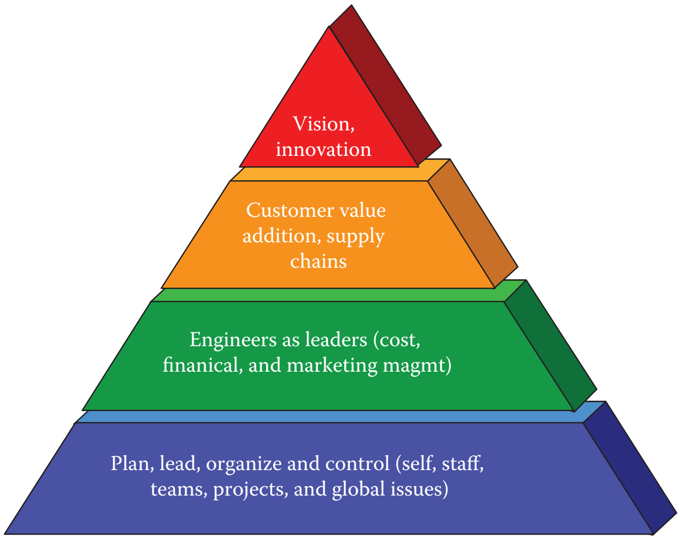

FIGURE 14.5
Leadership pyramid.

main thing: achieving strategic differentiation and operational excellence through innovation and technology.

As depicted in Figure 14.5, this book is intended to assist STEM professionals and leaders in creating individual leadership pyramids that, when constantly nurtured and reinforced brick by brick, allow them to be recognized and remain visible as leaders for a long time to come.

How can STEM professionals and managers exercise their leadership roles to add value to the stakeholders of the company? The model depicted in Figure 14.6 illustrates a possibility. From left to right, engineering managers apply resources (as shown in the second column from the left), initiate specific processes (as shown in the third column from the left), create values (as shown in the fourth column from the left), and eventually benefit specific stakeholders (as shown in the right-hand column).

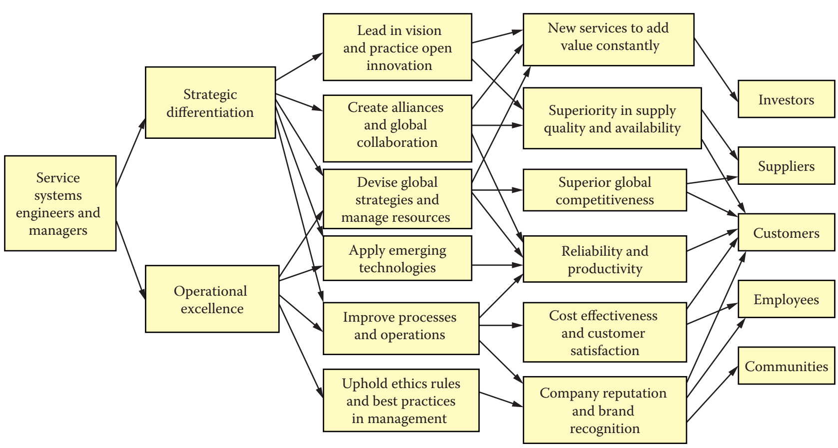

FIGURE 14.6
Emphasis on strategic differentiation and operational excellence.

There are three specific resources that STEM professionals and managers may activate: product design, ERP and other web-based tools, emerging technologies, and vision and innovations. STEM professionals and managers utilize product design, ERP, and other web-based tools to manage global supply chains, strengthen products, effect the company's e-transformation, achieve optimization of global resources, and supervise global projects and teams. They use emerging technologies to develop products, promote the e-transformation of the company, and achieve best practices with respect to the environment. They lead with vision and innovations to spearhead product design and development, initiate e-transformation, optimize the use of global resources, manage global projects and teams, and create best practices with respect to the environment, ethics, and other community values.

The successful management of global supply chains leads to better, cheaper, and faster products and services and more effective collaboration with suppliers. The process of developing products and services with the help of web-based tools or other emerging technological aids leads to better, cheaper, and faster products and services, more effective collaboration with suppliers, and a stronger global competitive stance for the company. E-transformation of the company brings about swifter decision-making and a more robust global competitiveness. Optimization of global resources leads to stronger global competitiveness, improved employee satisfaction, and enhanced innovations. Moreover, as the company follows best practices with respect to ethics and the environment, it projects a superior image of corporate citizenship to the public.

The creation of better, cheaper, and faster products and services adds value to customers. Improved collaboration with suppliers makes suppliers happy. Better and faster company decision-making pleases the shareholders. Stronger global competitiveness adds value to shareholders. Improved employee satisfaction and cutting-edge innovations add value to both shareholders and employees. Excellent corporate citizenship favors communities as well as the employees.

To confront the management challenges of the twenty-first century, STEM professionals and leaders need to manage from the inside as well as from the outside, to lead from the present to the future, and to act locally and think globally. Table 14.1 contains descriptions of these alternative viewpoints.

On the *inside*, STEM professionals and managers plan, organize, lead, and control to implement projects and programs. They manage people, technologies, and other resources to add value to their employers. They strengthen the company's core competencies and come up with products with features that customers want. They effectively define (by ABC

TABLE 14.1

Six-Dimensional Challenges

Manage/Lead/Act/Think	Focuses
Inside	Core competencies, cost and quality control, production and process excellence
Outside	Emerging technologies, supply chains, market orientation, customer relationship
Today	Implement all projects to achieve operational excellence, do the thing right
Tomorrow	Apply creativity and innovation, do the right things, and lead in creating strategic differentiation
Local	Build local strengths and unique partnerships, implement local adjustments and customization
Global	Global resources, global scale and scope, global mind-set, global partnerships and savvy

and Monte Carlo simulations), monitor, and control costs. They appraise the company's financial position and seize the right moments to initiate major projects with high technological content. These projects are supported by rigorous financial analyses in order to meet tough corporate evaluation criteria.

On the *outside*, STEM professionals and managers keep abreast of emerging technologies and screen new technologies that might affect the company's products or services. They proactively identify and introduce web-based tools related to product design, project management, plant operations, facility maintenance, and knowledge management to improve the company's current operations. They define best practices in the industry, emulate them as standards by which to evaluate their own in-house practices, and relentlessly strive to surpass these best practices. They look for potential supply chain partners whose alliances could create competitive advantages for their employers in production, distribution, product customization, or after-sales service. They are sensitive to the constant need to improve the management of customer relationships. Through the use of web portals and other current technologies, they meet this need. They strive to add value to all stakeholders—customers, employees, suppliers, investors, and the communities in which the company operates.

For the *present*, STEM professionals and managers focus on keeping the company smoothly operating by "doing things right." They pay attention to details. They introduce a balanced scorecard to make sure that both financial and nonfinancial metrics are selected and deployed to monitor and evaluate the company's performance. They attempt to continuously improve current company operations. They take care of assignments (e.g., cost control and waste elimination) that should be accomplished for the company to achieve business success in the short term.

For the *future*, STEM professionals and managers seek e-transformation opportunities to create corporate competencies in the long term. These are profit-producing opportunities that may be created by significantly enhancing the value of the company's products to customers through, for example, distribution, price, service, features, and ordering processes. STEM professionals and managers develop and introduce new products in a timely manner to ensure sustainable profitability for the company in the future. They envisage a vision for the future, contribute to new company strategies related to technology, and assist company management in defining "the right things to do."

At the *local* level, STEM professionals and managers seek to best utilize the resources available (e.g., people, technology, and business relationships) to achieve the company's objectives. They adjust to local conditions and take lawful, ethical, and proper actions to discharge their daily responsibilities. They maintain their local networks of professional talents and business relationships to improve the company's productivity. They communicate their experience and preserve lessons learned so that others at different sites within the company may benefit.

At the *global* level, STEM professionals and managers are sensitive in their pursuit of the optimal use of location-based resources to realize global economies of scale and scope and to derive both cost and technology advantages for their employers. They create global networks of professional talents and business relationships and exploit innovative business opportunities. As companies pursue globalization over time, these professionals acquire a global mind-set, become globally business savvy, and ready themselves to exercise leadership roles in international settings.

These six-dimensional challenges are indeed interrelated, as illustrated in Figure 14.7. Because many companies are affected by the rapid advancement of technology and the fast-paced advancement of globalization, the new millennium both creates ample

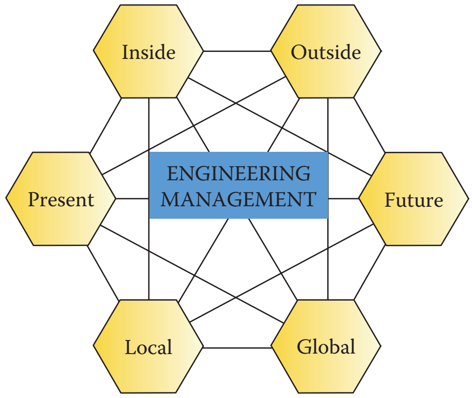

FIGURE 14.7
Interrelationship between six-dimensional challenges.

opportunities for, and poses new challenges to, engineers and engineering managers (Kouzes and Posner 2012; Drucker 2014; Deep and Sussman 2000; Palus and Horth 2001; Jacobson 2000). Those STEM professionals and managers who capture these new opportunities and meet these new challenges will be rewarded.

Example 14.5

In the new millennium, innovative ideas, rather than physical assets, will enable companies to compete effectively in a global-knowledge economy. Usually, innovative ideas come from knowledge workers who are typically inventive, independent, and mobile. No single company is capable of "chaining" down these workers, as they are happy to be there, but ready to move on at any time.

It is likely to be a major challenge for STEM professionals and managers to foster innovation on a continuing basis in such an environment. What might be a good strategy for STEM professionals and managers to adopt in order to secure a constant flow of innovations that are potent enough to sustain the relative competitiveness of their enterprises?

Answer 14.5

During the last century, a number of well-known companies (IBM, AT&T, Dupont, GE, Merck, and others) achieved remarkable business success by emphasizing R&D in-house and innovation on the inside. They proudly advertised the number of U.S. patents they received per year as an indication of their inventive power. They kept a large number of experts on their payroll to foster innovations. Many of these giants have since left their historical mission of inventive discovery. Some have also abandoned the past practice of not sharing with others those inventions that did not fit their respective corporate strategies at the time.

Companies in the knowledge economy have implemented a flexible technology strategy with great success. Known examples include Microsoft, Cisco, Dell, and Pfizer. Because skilled workers are mobile, companies can no longer count on in-depth development of innovations on the inside. In order to secure a constant inflow of creative ideas, they pursue open innovations (e.g., by acquisition, joint venture, or contract research) deemed useful to foster their corporate objectives. The emphasis has been shifted from in-depth innovation within a discipline to innovation with breadth and integration across disciplines.

P&G is known to be an aggressive acquirer of creative ideas from the outside. In 2001, 10% of P&G products came from outside sources, and this percentage is expected to have risen to 50% by 2006. P&G has also decided to make a patented technology available to outsiders, including competitors, if it is not used by at least one internal business unit within three years (Chesbrough et al. 2014; Griffin et.al. 2014).

To meet the new challenge of creating a constant flow of creative ideas, STEM professionals and managers must scan promising innovations on the outside (e.g., universities, start-ups, competitors, and others) and integrate them for profitable internal applications. Any inside innovations that do not conform to the corporate objectives are to be aggressively marketed to outside companies to generate licensing revenues.

Example 14.6

Forecasting future market conditions and technologies is a difficult, but necessary, skill for companies striving to sustain business success. Looking out for emerging technologies should be the primary role of STEM professionals and leaders.

What might be a good strategy for engineering and technology managers to become sensitized to forecasting technology and scanning emerging technologies so that they fulfill their important role as technology "gatekeepers"?

Answer 14.6

Different engineering and technology managers will have different preferences in fulfilling this important role of forecasting. One possibility is to adopt the following logical sequence of steps:

1. Compose a "wish list" of technologies that would make the company's current products cheaper, faster, and better. Define desirable new product features based on customer inputs and the technologies required for their development. Determine new product concepts and the requisite technologies that might be compatible with the current product lines marketed by the company.
2. Understand some of the emerging technologies noted in the literature (e.g., see Table 2.2).
3. Identify the useful technologies that might be available during the next 5–10 years to support the current products, product enrichments, or new product concepts.
4. Assess the development activities associated with these useful technologies in universities, start-ups, technology incubator firms, contract research companies, or other organizations, both domestic and global, to gauge their quality and readiness for commercialization.
5. Make specific recommendations in a timely manner to secure the supply of such new technologies for enhancing the commercial success of the company's products.

Example 14.7

"Think globally and act locally" has been the general guideline offered to managers at the headquarters of global companies that seek to achieve success in the global markets. The logic is rather compelling.

For those STEM professionals and managers of global companies that operate in local regions or markets, perhaps the guideline should be "Think locally and act globally." What is your opinion on these guidelines?

Answer 14.7

The principal objective of requiring headquarters managers of global companies to "think globally and act locally" is to make sure that the company's products and services are sufficiently adjusted to the needs of local markets, while enjoying the economies of scale advantages of being global.

Numerous local managers of global companies have created innovative strategies and achieved remarkable success, based on their understanding of the culture and customs in local markets. Oftentimes, the same insight and innovative strategies need only be applied to other regions, with only minor modifications, for the headquarters managers of the global companies to realize the economies-of-scope advantages on a global basis.

Das (1993) spoke in favor of the concept of "thinking locally and acting globally," as a result of his personal experience as a local manager of P&G in India. It is indeed true that for local managers, they need a different reference, compared with their counterpart at the company's headquarters, to be effective in making valid contributions.

14.9 Conclusions

This chapter summarizes the foundational skills and capabilities that all STEM professionals should possess.

In addition, there are 12 groups of skills and knowledge they ought to master, as graphically represented by the *Three-Decker Knowledge Architecture*. STEM professionals are advised to become versed in these skills and capabilities by self-study or through learning opportunities sponsored by their enterprises.

For STEM professionals to make valuable contributions toward creating strategic differentiation and operational excellence for their enterprises, they are encouraged to do the following:

1. Practice the DeepThink methodologies (see Appendices 10.A and 10.B in Chapter 10), or other idea generation techniques, to become proficient in generating creative ideas and offering novel solutions, on a continuous basis, to problems or issues of importance to their enterprise.
2. Seek opportunities to implement the best-practice methods available in industries to upgrade all in-house work processes and organize teams to improve the productivity and efficiency of increasingly complex processes.

The ability of an enterprise to shape outcomes, such as pursuing its important goals of creating strategic differentiation and operational excellence in order to satisfy the expectations of all of its stakeholders (e.g., customers, employees, investors, suppliers, and community), rests entirely on the shoulders of its employees.

Industrial sectors are growing worldwide, and they assume increasingly dominant roles in all developed and developing economies, thus offering high-growth job opportunities to those who are properly prepared. In order to become top employees in any enterprise, STEM professionals and leaders need to take charge and exercise their leadership roles in meeting the challenges of the future. In this respect, the following "Take Charge" model may be useful as a guide:

T: Take some risks by trying out novel ideas or projects, which may benefit from some testing and experimentation.

A: Apply best practices, proven productivity tools, and emerging technologies currently in development to enhance operational excellence.

K: Know what is yet to be learned (any part of the domains as illustrated in the Three-Decker Knowledge Architecture framework, new techniques to pursue open innovation, and new customer demands in the marketplace) to become prepared for making valuable contributions.

E: Exercise leadership in conjunction with innovation development, team building, staff selection and training, and the management of projects, programs, supply chain, and other activities, especially those facing the customers.

C: Customize product/service offerings to the specific needs of customers in order to enhance the value to them.

H: Harness corporate insights by managing and reusing the corporate knowledge base to produce visions for the future.

A: Acquire the skills, mind-set, and attitude to work well with customers and people at all levels within the enterprise, as well as a set of good habits of thinking innovatively and productively.

R: Ready the enterprise and self for meeting the six-dimensional challenges.

G: Generate new product/service ideas by being proficient in invoking DeepThink or other idea-creating methods to promote strategic differentiation.

E: Evaluate new global opportunities and offer creative initiatives.

STEM professionals and leaders are advised to take charge by acquiring the knowledge and skills indicated here, applying them to achieve strategic differentiation and operational excellence for their employers, taking charge to strengthen the short-term performance and long-term health of their enterprises, and satisfying the expectations of all their enterprises' stakeholders.

QUESTIONS

1. Sustainable development refers to work that simultaneously satisfies economic, social, and environmental requirements (United Nations 2002). It is self-evident that work must be economically viable so that customers are willing to pay for the work supplied. Work must also be safe and otherwise socially compatible. Furthermore, work needs to be environmentally acceptable in that harmful discharges are minimized, wastes are decreased, material and energy resources are conserved, and any other detrimental impact on the environment is minimized.

   Some academics suggest that it is the engineer's responsibility to attain the ideals of sustainable development. They view it as the major challenge facing engineers in the future (Cruickshank 2003). Do you agree with this notion? Why or why not?

2. Leading technological innovation will be a major challenge for engineering managers in the new millennium. What are some of the success factors for technological innovation?
3. The new millennium is expected to see continued changes in communications technologies, business practices, worker diversity, customer empowerment, and marketplace conditions. Name a few leadership qualities that are deemed essential for engineering managers to achieve success in the new millennium.
4. U.S. productivity has improved noticeably in recent years, averaging 4%–5% per year, while the U.S. economy grew by only 3.5%. The gain in productivity was due, in large part, to the use of technology, in addition to longer working hours by those who are lucky enough to have jobs. According to the Economic Policy Institute, the average U.S. worker has added 199 hours to a year since 1973. The United States achieved per hour productivity of $32, compared with $38 for Norway, and $34 for Belgium. In other words, U.S. workers are simply working longer, not necessarily better or smarter. They take less annual vacation time (only 10.2 days, on average), compared with 30 days in France and in Germany.

   At the same time, a large number of U.S. companies are aggressively outsourcing work to low-wage countries, such as China, India, the Philippines, and Mexico. A 2003 study released by the University of California at Berkeley indicates that as many as 14 million U.S. service jobs are in danger of being shipped overseas.

   Who is responsible for this peculiar position that U.S. workers are being forced into? How can U.S. companies meet the new challenge of improving the quality of life for their workers, without sacrificing the companies' relative competitiveness in the marketplace?
5. In the new millennium, speed to market will be a major harbinger of competitiveness. "The early bird gets the worm," as the saying goes. How can engineering managers meet this challenge by leading their companies to be the first movers?

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Appendix: Selected Engineering Management and Business Cases

The case method is well established and widely practiced in management schools. Science, technology, engineering, and math (STEM) professionals and managers are advised to consult a recent publication regarding the advantages of learning from cases (Source: Wambaugh, Eugene (2015), *The Study of Cases: A Course of Instruction in Reading and Studying Reported Cases, Composing Head-Notes and Briefs*, Forgotten Books.)

Samples of engineering and business management cases are selected to assist STEM professionals and managers in gaining management and business perspectives. These cases, illustrating the complex engineering and management issues involved, may be studied to augment the topics covered in this book. The author has used all of them over a period of time with success. STEM professionals and managers are strongly encouraged to study these and other cases to derive useful lessons from them.

Class surveys indicate that engineering students generally like case discussions, as they enhance critical thinking and stimulate active participation. They like the fact that well-organized case studies are the next-best avenues, besides working in the right industrial settings, for them to acquire useful experience in dealing with real-world management issues. They understand also that the principle of "more in and more out" applies here, in that the more effort they put in to preparing themselves for the case discussions in class, the more valuable insights they will get out of the cases discussed.

It is generally advisable to specify a list of questions for each case ahead of time for students to focus their preparation on. It is equally important to ensure that the discussions are not dominated by a few students in the class, that most students are encouraged to speak up, and that the discussions are driven by thought-provoking questions. Each case takes, on average, the class time of about 60–90 min. Usually, students like the instructor to give them a written case summary that captures the salient points of the case discussion. Past experience indicates that asking students to summarize in writing what lessons they have learned from each case, without reiterating the case details, helps them to internalize the "take-away" messages.

STEM professionals and managers may purchase case materials from the publisher, Harvard Business School Publishing Company (http://www.hbsp.harvard.edu). Any academic educator may register at the same website of Harvard Business Online for Educators free of charge. Once registered, the educator may download a free copy of any of these cases for evaluation purposes. To use these cases in class, students need to purchase the original copies, possibly at an academic discount price. For information regarding order processing, contact 1-800-545-7685 or www.hbsp.harvard.edu.

Twenty-one cases are included here (see Table A.1). Three of these cases (Nos. 8, 13, and 15) are Harvard Business School's best-selling cases. Table A.1 groups the cases according to the main subjects covered in this book.

The set of cases listed in Table A.1 covers technology products (both industrial and consumer) of large and small firms engaged in domestic and international businesses. The cases outlined in Table A.2 address various engineering management issues discussed in this book. Table A.2 relates these cases to the chapters involved.

TABLE A.1

Classification of Engineering and Business Management Cases

Case Reference	Subjects Covered	Primary Discipline	Products Involved
Case No. 1	Implementation of e-commerce, Internet, information technologies, computer networks	Management of information system	Industrial gases (oxygen, nitrogen, argon)
Case No. 2	Product positioning based on exterior styling, computer-aided technologies, organizational and process changes	Operations management	Automobiles
Case No. 3	Product development to overcome negative publicity, pricing strategy, business strategy, product management	Marketing	Oilfield pumping motors
Case No. 4	Marketing fundamentals of industrial products (pricing, product development, public relations, sales, target markets)	Marketing	Equipment to dispense adhesives
Case No. 5	Manufacturing cost accounting (budgeting, accounting, financial management, operations management)	Accounting and control	Manufactured goods
Case No. 6	Distribution channels and conflicts (e-commerce, Internet, marketing, pricing, product management, retailing)	Marketing	Printers
Case No. 7	Operations management (considering both technical and human issues in a changing environment)	Operations management	Automotive components
Case No. 8	Organizational design at various stages of company development (entrepreneurial management, divisional structure)	Human resources management	Technology services
Case No. 9	Management of teams (group behavior, innovations, product development, project management, collaboration)	Organizational behavior and leadership	Various technical products
Case No. 10	Product development and business teams (integration of team capabilities, marketing, manufacturing, operations management)	Operations management	Winchester disk drive

Case No. 11	Strategic decision-making involving business or production expansion (trade-offs of options, competitive strategies, organizational behavior)	Competitive strategy	Automobiles
Case No. 12	Problem solving related to supply-chain difficulties (flexibility, just-in-time delivery, production planning and control, operations management)	Operations management	Commercial motors
Case No. 13	Activity-based costing (cost allocation, pricing, profitability analysis, cost analysis)	Accounting and control	Brass valves, pumps, and flow controllers
Case No. 14	Capital budgeting decision related to an enterprise resource planning system (cash flows, working capital, NPV analysis, financial analysis)	Finance	Consumer appliances
Case No. 15	Product and brand management (brand image, product positioning, international competition, marketing strategy)	Marketing	Power tools
Case No. 16	Niche marketing (channel conflicts, customer segmentation, product and service offering, competitive strategy)	Operations management	Computers
Case No. 17	Global challenges (organizational behavior, global leadership, management of change, manufacturing operations)	General management leadership, strategic planning	Automobiles
Case No. 18	Start-up challenges (global strategy, alliances, international businesses)	Competitive strategy	Semiconductors
Case No. 19	Cooperative strategy, distribution channels, high-technology products, strategic marketing plan	Entrepreneurship	Software products
Case No. 20	Resource allocation decisions and interactions among groups	Team operations and corporate governance	Plastics products
Case No. 21	Supply strategies for global markets and decision-making	General management	Medical products

TABLE A.2

Chapter Coverage Corresponding to Cases

Chapter	Chapter Coverage	Applicable Cases Number
1	General introduction	
2	Planning	Case No. 17 (Planning for company revival)
3	Organizing	Case No. 8 (Organizational design)
4	Leading	Case Nos. 9 and 10 (Teams)
		Case No. 11 (Decision-making using Rational method)
		Case No. 17 (Leadership)
		Case No. 20 (Decision-making in groups)
5	Controlling	Case No. 7 (Operations management)
		Case No. 12 (Problem solving)
6	Cost accounting	Case No. 5 (Manufacturing, accounting)
		Case No. 13 (Activity-based costing)
7	Financial accounting and management	Case No. 14 (Income statement and balance sheet)
8	Marketing management	Case No. 15 (Product/brand management)
		Case No. 2 (Product positioning)
		Case No. 4 (Marketing management)
		Case No. 16 (Niche marketing)
		Case No. 6 (Distribution channels)
		Case No. 19 (Strategic marketing)
9	Engineers as managers and leaders	Case No. 1 (E-transformation)
10	Creativity and innovation	
11	Ethics in engineering management and workplace	
12	Operational excellence	Case No. 3 (Product development)
13	Globalization	Case No. 18 (Global business)
		Case No. 21 (Global supply strategy)
14	Engineering management in the new millennium	Case No. 19 (New challenges)

List of Cases

Case No. 1: F. Warren McFarian and Melissa Dally. “Electronic Commerce at Air Products.” *Harvard Business School Case*, No. 9-399-035, August 19, 1998.

Case No. 2: Stefan Thomke and Ashok Nimgade. “BMW AG: The Digital Auto Project (A).” *Harvard Business School Case*, No. 9-699-044, November 1, 2001.

Case No. 3: E. Raymond Corey. “Dominion Motors and Controls Limited.” *Harvard Business School Case*, No. 9-589-115, September 23, 1992.

Case No. 4: John A. Quelch. “Loctite Corporation: Industrial Products Group.” *Harvard Business School Case*, No. 9-581-066, Rev. July 15, 1991.

Case No. 5: William J. Bruns, Jr. “Monterrey Manufacturing Company.” *Harvard Business School Case*, No. 9-197-023, Rev. September 13. 2004.

Case No. 6: Rajiv Lal, Edith D. Prescott, and Kirthi Kalynam. “HP Consumer Products Organization: Distributing Printers via the Internet.” *Harvard Business School Case*, No. 9-500-021, Rev. March 22, 2000.

Case No. 7: Amy C. Edmondson and Mikelle F. Eastley. “GM Powertrain.” *Harvard Business School Case*, No. 9-698-008, April 26, 2000.

Case No. 8: Nitin Nohria and Julie Gladstone, “Appex Corp.” *Harvard Business School Case*, No. 9-491-082, February 10, 1992.

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Case No. 10: Steven C. Wheelwright and Clayton Christensen. “Quantum Corp.—Business and Product Teams.” *Harvard Business School Case*, No. 9-692-023, February 17, 1992.

Case No. 11: Anita McGahan and Greg Keller. “Saturn Corp.: Module II Decision.” *Harvard Business School Case*, No. 9-795-011, August 18, 1994.

Case No. 12: David Upton and Andrew Matherson. “EG&G Rotron Division.” *Harvard Business School Case*, No. 9-695-037, April 14, 1997.

Case No. 13: William J. Bruns, Jr. “Destin Brass Products Co.” *Harvard Business School Case*, No. 9-190-089, April 24, 1997.

Case No. 14: Richard S. Rubak, Sudhaker Balachadran, and Aldo Sesia. “Whirlpool Europe.” *Harvard Business School Case*, No. 9-202-017, November 15, 2003.

Case No. 15: Robert J. Dolan. “Black and Decker Corporation (A): Power Tools Division.” *Harvard Business School Case*, No. 9-595-057, March 29, 2001.

Case No. 16: Frances X. Fei, Youngme Moon, and Hanna Rodriguez-Farrar. “Gateway: Moving Beyond the Box.” *Harvard Business School Case*, No. 9-601-038, May 9, 2002.

Case No. 17: Michael Y. Yoshino and Masako Egawa. “Nissan Motors Co. Ltd.—2002.” *Harvard Business School Case*, No. 9-303-042, February 14, 2006.

Case No. 18: George Foster, Christopher S. Flanagan, Paul L. Wattis, and Phillis Wattis. “NetLogic Microsystems.” *Stanford University Case*, No. E94, June 28, 2001.

Case No. 19: Andrian B. Ryans. “FastLane Technologies.” *Richard Ivey School of Business, University of Western Ontario Case*, No. 98A006, November 10, 1999.

Case No. 20: Anonymous. “Peterson Industries.” *Harvard Business School Case*, No. 9-396-182, February 12, 1996.

Case No. 21: Tarun Khanna. “General Electric Medical Systems.” *Harvard Business School Case*, No. 9-702-428, October 27, 2005.

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