W. Richard Bowen

Engineering Ethics

Challenges and Opportunities

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Preface

This book seeks to set a new agenda for engineering by developing a key challenge: *can the great technical innovation of engineering be matched by a corresponding innovation in the acceptance and expression of ethical responsibility?*

Central to the elucidation of this agenda and challenge is the consideration of engineering as a practice, a coherent and complex endeavour of persons for the benefit of other persons and the communities in which they live. The practice of engineering seeks to promote the wellbeing of persons in communities and also their agency, their possibilities to carry out desirable and beneficial actions. That is, engineering is essentially an enabling activity.

Professional engineers have at their disposal a range of knowledge, skills, techniques and technologies of great potential. Such capabilities provide engineers with opportunities to enhance the wellbeing and agency of others in many ways. This book analyses these opportunities using examples from three key areas: engineering for peace, engineering for health and engineering for development. Furthermore, specific ways in which the acceptance and expression of ethical responsibility by individual engineers can be promoted are described, particularly participation in social settings that stimulate generous ethical action. Strategies for convincing decision makers of the ethical opportunities of engineering are proposed, including a human rights approach and consideration of engineering power, the ability to attain desirable social and political outcomes through the peaceful use of engineering capabilities. Future prospects for increasing the acceptance and expression of ethical responsibility by engineers in an extended time frame are envisaged.

This book provides engineers with a coherent and challenging new vision of their profession. It seeks to stimulate their ethical imagination by providing a convincing description of engineering in terms of the lives that it can enable persons and communities to live, in contrast to the more conventional focus on engineering as the means of providing ingenious technological artefacts. It seeks to promote a new perception of engineering among engineers, decision makers, philosophers and the general public. It is particularly hoped that the book will stimulate a commitment to innovation in the acceptance and expression of ethical responsibility by engineering students and young engineers.

I am thankful for the many discussions with colleagues that have benefited the development of this book. Such development has also benefited from the questions and discussions that have followed invited lectures to engineers, scientists, philosophers, theologians, political scientists and lawyers. I particularly wish to thank Iselin Eie Sokhi for perceptive comments on all aspects of the text as it was being written. During the final preparation, the encouragement and effectiveness of Anthony Doyle and Gabriella Anderson at Springer have been much appreciated.

Any new vision looks to a better future. This book is hence dedicated to Annika Eie Nicholas in the hope that she may grow up in a world in which engineering truly promotes peace, health and development for all.

Wales, September 2013 W. Richard Bowen

Contents

Chapter 1
Introduction

Milton tried to educate the children in his academy in the knowledge of physics, mathematics, astronomy and the natural sciences. In the mid-seventeenth century, Dr. Johnson was to observe that 'Prudence and justice are preeminences and virtues which belong to all times and all places; we are perpetually moralists and only sometimes geometers [1].

1.1 Engineers, Engineering and Ethics

Engineers are renowned for their great technical ingenuity. This ingenuity has profoundly changed the world we live in. Many of these changes are hugely beneficial, such as clean water production and sanitation, energy generation, large-scale pharmaceutical manufacture, hygienic food processing, functional buildings, transport infrastructure, mechanical devices, medical diagnostic equipment, instrumentation, computing and telecommunications. Some other changes are hugely deleterious, such as weapons manufacture and proliferation, damage to the natural environment and activities that directly disadvantage vulnerable populations. An important underlying factor giving rise to such widely differing outcomes of engineering activity is that the engineering profession as a whole has given a high priority to technical ingenuity whilst giving only muted attention to ethical responsibility. This is exemplified in the almost entirely technical content of many university engineering courses and the highly technical focus of most commercial engineering enterprises. Such imbalances give rise to the greatest challenge to contemporary engineers, and the central concern of the present book: *can the great technical innovation of engineering be matched by a corresponding innovation in the acceptance and expression of ethical responsibility?*

The prioritisation by engineers of technical ingenuity over ethical responsibility has become mirrored in public perception: engineers are often perceived as being primarily technically inventive nerds or geeks. As a result, their positive contribution to the wellbeing of persons and communities is often poorly appreciated. Such misunderstanding is especially unfortunate when it influences the views of

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serious thinkers, opinion formers and decision makers. Sometimes such views are expressed in strikingly negative terms. For example, the political theorist Hannah Arendt suggested that those responsible for 'scientific progress and technical developments' should not be trusted because they 'move in a world where speech has lost its power' [2]. Arendt expressed this view in the context of the development of atomic weapons. She implies that those who carried out such development were not just naïve, but more seriously lacked true humanity. They had forgotten that they were only sometimes engineers and that as human beings they needed to show ethical responsibility at all times. That Arendt's grave concern has some validity is confirmed by the views of Robert Oppenheimer, the director of the Manhattan project, 'When you see something sweet, you go ahead and do it and you argue about what to do about it only after you have had your technical success. That is the way it was with the atomic bomb' [3]. The continuing development of nuclear weapons in both existing nuclear states and in other states shows that Arendt's concern remains pertinent.

Fortunately, not all perceptions of engineers are so negative. Consider the following quotation from a major work of the novelist Aleksandr Solzhenitsyn:

> An engineer? I had grown up among engineers, and I could remember the engineers of the twenties very well indeed: their open, shining intellects, their free and gentle humour, their agility and breadth of thought, the ease with which they shifted from one engineering field to another, and, for that matter, from technology to social concerns and art. Then, too, they personified good manners and delicacy of taste; well-bred speech that flowed evenly and was free of uncultured words; one of them might play a musical instrument, another dabble in painting; and their faces always bore a spiritual imprint [4].

Among such early twentieth century engineers was Pavel Florensky, a brilliant polymath whose original work was carried out at the highest levels in theology, philosophy, the theory and history of art, mathematics, an astonishingly wide range of science and electrical engineering [5]. The scope of his technical work is truly astounding, including books such as *Dielectrics and their Technical Applications*, an estimated 134 entries in a *Technical Encyclopedia* and numerous research articles (with a range that includes 'Sunspots during an eclipse', 'Table for functional classification of galvanic elements and batteries', 'World energy resources' and 'New material from maize waste'). His appointments included a position at the State Planning Commission for the Electrification of the Soviet Union,[1] the directorship of the Department of the Science of Materials in the State Experimental Electrotechnical Institute, and leadership of an expedition to report on mineral wealth in the Caucasus. He also wrote on a formidable range of theological and philosophical topics as well as writing a seminal account of the history, techniques and spiritual significance of icons. Much of this work took place during a time of great persecution of intellectuals and priests following the

[1] The continuing need for the provision of electricity in the developing world will be considered in Chap. 5.

Russian revolution of 1917. However, Florensky's great engineering abilities, such as his contribution to the electrification of Russia, gave him a measure of protection for many years—he was too useful to purge. His personal motivation was the wellbeing of his fellow citizens. Remarkably, he continued to dress as an Orthodox priest in cassock, cross and cap, keeping a beard and long hair—even, so it is reported, whilst addressing an Electrotechnical Conference at the express invitation of Leon Trotsky. Eventually he was arrested on false charges, imprisoned in labour camps and executed in 1937.

Engineers such as Florensky provide a great source of inspiration as an example of a life well lived. Not all engineers lead lives as dramatic as that of Florensky. Most engineers lead quiet lives of modest achievement. However, there is increasing awareness that paying more attention to ethics can enrich all engineering. One way in which such increased awareness has been realised is through the development of ethical codes or statements of ethical principles for engineering.

1.2 A Statement of Ethical Principles

Professional institutions associated with the various sub-disciplines of engineering (such as civil engineering, mechanical engineering, electrical engineering and chemical engineering) in the UK have for many years published ethical codes for their members. However, these were numerous and rather diverse in character.[2] Therefore, the pre-eminent engineering organisation in the UK, the Royal Academy of Engineering,[3] has recently, in collaboration with the Engineering Council UK, which regulates the engineering profession in the UK, and leading professional engineering institutions developed a *Statement of Ethical Principles* [6] that applies to all engineers, whatever their sub-discipline. The professional engineering institutions have pledged their support for the *Statement*, accepting it as a set of guiding principles for their members. This *Statement* is hence both up-to-date and recognised as authoritative across the diversity of the engineering profession. The process of development of the *Statement* has also generated renewed interest in engineering ethics. The full text of the *Statement* is given in the Appendix to this chapter.

[2] For historical reasons, the engineering profession has a complex institutional structure. Thus, there are 36 institutions representing various sub-disciplines of engineering in the UK. A few are large (such as those for the sub-disciplines mentioned in the main text) and many are small. Their existing ethical codes showed significant variation even though they were based on a simple pattern provided by the Engineering Council UK. This section refers to the UK, but comparable institutions and initiatives exist in many other countries.

[3] The Royal Academy of Engineering is the UK's national academy of engineering, fulfilling roles comparable to those of the Royal Society in science and the British Academy in humanities and social sciences.

The *Statement* opens with a challenging description of the work of engineers:

> Professional engineers work to enhance the welfare, health and safety of all whilst paying due regard to the environment and the sustainability of resources. They have made personal and professional commitments to enhance the wellbeing of society through the exploitation of knowledge and the management of creative teams.

This is notably a description of a human endeavour: it describes the activities of persons for the benefit of other persons. It should be noted that the *Statement* refers to the purposive social goal of engineering as being 'to enhance the welfare, health and safety of *all*'. This is a very demanding aspiration, which includes communities beyond our usual boundaries and the individual persons in those communities.

The *Statement* then presents four 'fundamental principles' that can serve as guidance to engineers as they seek to meet these high aspirations: *accuracy and rigour; honesty and integrity; respect for life, law and the public good; responsible leadership, listening and informing*. The full text of the *Statement* provides a further description of how each principle may be understood. A more recent Royal Academy of Engineering publication has provided guidance as to how the principles may be applied to some specific dilemmas [7]. Though these principles may be applied throughout a professional engineer's activities, they are each particularly relevant for differing aspects of his or her work, as will be discussed in Chap. 2. In common with other modern professional codes of ethics, the *Statement* emphasises *what* should be done. This is not simply a characteristic arising from the brevity of the *Statement*. Such an emphasis is retained even in considerably longer codes of ethics for engineers, such as that of the US National Society of Professional Engineers [8].

The *Statement* can provide a basis for addressing the many professional challenges and opportunities that a professional engineer may encounter. Many of these arise particularly in association with the special characteristics of engineering work. For example, the *Statement* provides a starting point for addressing the great present challenge to the engineering profession, the imbalanced prioritisation of technical ingenuity over ethical responsibility: the technical content of engineering can be so intellectually stimulating that the real goal of engineering, enhancing human wellbeing, may be forgotten [9]. Again, many engineers work under substantial time and financial pressures as employees of sizeable organisations. Such pressures and the diffuse nature of ethical responsibility in large businesses can lead to reduced levels of moral reasoning. The *Statement* provides a primary source of ethical guidance in such circumstances.

However, a fuller account of the ethical challenges and ethical opportunities of engineering needs also to consider *why* and *how* desirable actions should be accomplished. Such considerations are especially important if there is to be real innovation in the acceptance and expression of ethical responsibility by engineers. For example, it is not uncommon for an engineer's work to affect primarily people who are distant in place and/or distant in time from where the work is conceived and planned, far from the place where engineered artefacts are constructed, and even far from the place where completed engineered artefacts are located. An engineer therefore needs to develop an ethical imagination so as to be sensitive to those affected by his or her activities. Again, achieving a balance of continuity and coherence in personal and professional life may be especially challenging for an engineer. The difficulties of balancing ethical responsibilities to those closest to us with the multitude of needs of those further away are familiar to many in the modern world. However, such balancing may be especially challenging for engineers as they possess skills that could be particularly useful for meeting the urgent necessities of those in direst need.

Ethical codes and statements of ethical principles can be read as sets of rules. However, merely to follow a set of ethical rules is not necessarily to *act* ethically. To really act ethically we need to be motivated by sincere intentions and more particularly to act on the basis of experience. Engineers know the importance of experience in their technical work, and the irreplaceable value of practical experience has been expressed well by Vernon Watkins in the opening lines of his poem *Fisherman* [10]:

> I learn as my fingers mend the net, what none without nets can know.

Aristotle applied such an approach to both technical and ethical matters:

> For the things we have to learn before we can do, we learn by doing, e.g. men become builders by building and lyre-players by playing the lyre; so too we become just by doing just acts, temperate by doing temperate acts, brave by doing brave acts [11].

Central to the present book is the view that engineering and ethics have a key likeness: they are essentially concerned with practical matters.

1.3 An Approach to Ethics: Persons in Communities

The origin of the word 'ethics' lies in the Greek *ethikos* referring to ethos, that is, distinctive character, spirit or attitude. For more than 2500 years, the documented quest of ethics has involved philosophical activities such as careful conceptual analysis and reflection. There now is a huge ethical literature.[4] However, ethics is not an apparently arcane theoretical aspect of philosophy but rather a vitally practical activity, for ethical decisions, how we choose to live and act, may have significant consequences for human wellbeing.

At the core of ethics lies an awareness of the uniqueness and value of each person. This is reflected in our sense of compassion and responsibility for those with whom we come into contact, especially those in need. The leading twentieth century philosopher Emmanuel Levinas has described ethics as arising out of the prioritisation of the demands that an other can make on us, which he designates by the notion of *the face*. He describes an ethical act as being defined by 'a response to the being who in a

[4] Gordon Graham has provided an excellent introductory work [12]. W. Richard Bowen has provided an introduction to the main ethical theories in an engineering context [13].

face speaks to the subject and tolerates only a personal response'[5] [14]. This view is based on the proximity of others generating a sensibility that leads to their needs taking priority. He even writes of the needs of others making us hostages, that we are above all responsible for others, indeed summoned to responsibility to the extent of substituting their needs for ours. Levinas does not develop his philosophical arguments in a conventional way but his message is nevertheless clear. In simple terms, and changing the metaphor, we need to hear the voice of others saying, 'It's me here, please help me!'. According to Levinas the individual's response should be, 'here I am for the others' [15]. Proximity in place and time is a crucially important motivator for such an ethical response, and hence we feel a special and immediate ethical responsibility for our families, friends and immediate neighbours.

Mention of families, friends and neighbours reminds us that we live in communities and that each person's wellbeing depends on the wellbeing of the community in which he or she lives. In practice each person belongs to several communities of different sizes which may be categorised in different ways, for example, a local neighbourhood, a city or a nation. Each person's wellbeing depends on the wellbeing of each community to which he or she belongs. Furthermore, in the modern world, each person's wellbeing also depends on the wellbeing of communities to which he or she does not belong: poverty and deprivation are major causes of conflict both within and between communities of all sizes. Until modern times, only a few very exceptional individuals could influence the lives of those outside their family and local community. In sharp contrast, today it is possible for most people in the more affluent parts of the world to influence the lives of not only those close by but also of others far away in other communities, through activities such as international trade, international travel and electronic communications. Achieving a balance of proximate and distant ethical commitments is especially challenging for professionals whose actions may have substantial influence far beyond their immediate community location in both place and time.

Our existence in communities means that the person-to-person or face-to-face relationship between two persons of the type implied by Levinas's description of an ethical act is an abstraction. Ethics is usually practised in communities, in the plural. The philosopher Enrique Dussel has given a profound account of such ethics in communities [16]. For Dussel the origin of ethics lies in basic experiences, action and participation in communities, rather than in theoretical analysis. He gives a simple example that provides a good illustration of how production and ethics in community are linked: the baking of bread. He writes of bread, 'It is a real, material product, something made. At the same time it is made *for another*. Therefore the relationship it incorporates is not only productive (person-to-nature) but also practical (person-to-person)' [17]. That is, the making of bread constitutes an ethical action as well as a practical action, and in many communities an economic action. Through networks of such actions our participation in communities gives rise to our mutual responsibility for each other.

[5] The original reads: 'c'est-à-dire réponse à l'être qui lui parle dans le visage et qui ne tolère qu'une réponse personelle c'est-à-dire un acte éthique'.

Dussel recognises that technologies are needed in modern societies if such practical-ethical actions are to be carried out effectively. These may result in the production of necessary basic goods, such as food, clothing, housing and healthcare. They may also result in cultural goods such as art, entertainment and knowledge. He also notes that we have a special responsibility to pay practical attention to the needs of the disadvantaged if the uniqueness and value of each person is to be respected. 'Good bye and good luck! Keep warm and well fed!' is not an ethical response for it does not include practical action to meet the needs of the other [18]. These are themes that will be developed in subsequent chapters.

Dussel also recognises that there are many factors in the world that act against such practical-ethical relationships. These may be powerful individuals who assert the good of their individuality against the community. They may be transnational companies that assert the good of the company against the communities in which they operate. They may be weapons manufacturers who trade in the 'bread of death'. They may be individuals or institutions that accumulate enormous amounts of capital. Here Dussel notes that the creative source of all wealth is work and not capital. Such enormous accumulation of capital he considers to be a type of trading in the life of those who produced the wealth. One of the means of guarding against such dangers is through participation in a *base community* in which the threats of society may be discussed and through which generous ethical action may be stimulated [19]. This is also a theme that will be developed in subsequent chapters.

It is possible to reach similar conclusions to the above by means of sophisticated philosophical analysis of a type that few engineers are likely to seek to penetrate. The practical approach that has been outlined in this section is suggested to engineers as it is in concordance with the practical nature of engineering. Indeed, philosophers more generally note that actions do not necessarily have to be grounded in sophisticated analysis: 'As Bernard Williams famously said, if I save my wife not *just* because she is my wife, but because I believe that husbands in general have special obligations to their wives, then I act on "one thought too many"' [20].[6] Furthermore, Bernard Williams has himself given the following advice to a leading practitioner of sophisticated ethical analysis, 'Korsgaard may want to consider someone who has tried to work out similar ideas in a different style, Levinas' [21].

1.4 Engineering and Technology: Contrasts and Some Illustrative Ethical Aspects

This is a book about engineering ethics rather than the ethics of technology. The nature of engineering will be examined in more detail in Chap. 2. However, there is an important distinction between engineering and technology, and hence the work of engineers and technologists, that is often overlooked and which requires

[6] Bernard Williams was a leading twentieth century UK philosopher.

attention here. Engineering is primarily a profession in which activities are carried out by persons for the benefit of other persons. Such activities involve the development or use of technology, but effective engineering does not necessarily involve the use of advanced technology. For example, effective engineering may involve an ingenious but technically simple means of meeting a genuine human need. Indeed, there is always a danger that engineers may become so involved in technical wizardry that the ethical dimension, the effect of the technology on others, may be neglected or lost. In contrast, the primary goal of technology and technologists tends to lie more in the direction of the development of artefacts. Furthermore, only a very sophisticated device is likely to win a technology prize, at least in developed countries. This contrast between engineering and technology is not sharp, for technologists may also have a concern for human benefit, but it has significant ethical implications as will become apparent in later chapters.[7]

Some aspects of this distinction between engineering and technology may be illustrated by considering the example of the bicycle. In the prestigious Reith lectures of 2005, Alec Broers, at that time the President of the Royal Academy of Engineering, provided the evaluation, 'I would argue…that most technologies, with the exception of those associated with weaponry, have had hugely beneficial effects for most people' [22]. However, Broers was very surprised by a poll that asked the public how they would rank Britain's greatest inventions. Over 50 % of 5,000 respondents had ranked the bicycle highest. He wrote, 'The bicycle is of course an ingenious, practical and sustainable invention, which has brought new opportunities to every stratum of society, and which continues to offer benefits today', but he considered that to put it ahead of inventions such as electricity, jet engines and vaccination was 'a profound misunderstanding of the contribution of advanced technologies in our lives' [23].

This assessment is valid, but it should also be noted that although a bicycle is a simple artefact it is an excellent example of effective engineering. Part of its ingenuity lies in its counter-intuitive nature: it is surprising that a person can so readily learn to balance and control a single-track vehicle, and mathematical simulation of the skills of bicycle riding is mathematically formidable, if not intractable. A bicycle has a modest cost, is non-polluting, considerably increases the distance that a person can travel in 1 day, and can carry loads of 10 times its weight [24]. Furthermore, the engineering development of bicycles continues. In the developed world this includes the engineering of ingenious designs of lightweight folding bicycles for commuting [25]. In the developing world bicycles are an important form of transport and may also be used to meet local needs in many ingenious ways: to husk corn, to sharpen knives, to charge batteries, to filter water, as an ambulance, to cross rivers, to pump water, to pump out a pit latrine, to wash clothes, and as parts of a windmill [26].

[7] Chapters 4 and 5 will also give examples of the benefits of the development of appropriate simple technology.

Misconceptions about engineering and misuse of technology also have influence in areas of human endeavour not usually associated with those disciplines, such as economics and banking. Amartya Sen, the Nobel Prize winning economist and philosopher, has argued that economics has two different origins [27]. The first he identifies as ethics, the good of man in a social context. The second he disparagingly refers to as an 'engineering' approach that is concerned primarily with logistical issues, with means rather than ends, seeing human beings in very narrow terms and characterising social institutions in rather simple form. Sen favours a synthesis of economics and ethics, and argues that such closer contact can be beneficial not only to economics but also to ethics. Though consideration of means is also important, Sen's terminology clearly involves a misunderstanding of engineering. Nevertheless, his work to create a synthesis of economics and ethics should find a parallel in the creation of a synthesis of the technical aspects of engineering and ethics, as will be described in later chapters.

The need to re-establish the link between ethics and economics has become more pressing recently with the move from a market economy to a market society in which all aspects of life are given monetary value and public discourse is drained of ethical reasoning [28]. This has especially created problems in banking where investment bankers have created complex financial instruments such as derivatives that are 'investments in investments, bets about bets', and do not recognise that the creative source of all wealth is work. It has been calculated that, 'By 2007 the international financial system was trading derivatives valued at one quadrillion dollars per year. This is ten times the total worth, adjusted for inflation, of all products made by the world's manufacturing industries over the last century' [29]. The role of technology in creating these problems has been well summarised in a recent important report on banking in London:

> [The] Big Bang [bank deregulation] took a great deal of direct contact out of the act of trading itself. According to that great Jewish philosopher, Emmanuel Levinas, the face of the other is the primary site of moral obligation. Having all the right rules and regulations in place is all well and good—indeed, they are obviously essential—but the real tug to do what is right comes from looking into the face of another and recognizing obligation to someone other than oneself. The fact that trading is now so heavily mediated by technology and less reliant on direct human contact may go some way to explain how a sense of moral obligation has come to feel less compelling [30].

One might, therefore, ask whether the extreme instability in the banking system could have been lessened if technology that retained appropriate human interaction had been in use. Indeed, now an engineer considering the banking crisis might see an ethical and business opportunity to develop technical means for banking that ensure human contact and that promote the recognition of ethical obligations to others. The importance of engineering that enhances real human relationships will be an important theme of subsequent chapters.

A useful guide to an ethical approach to life is the sequence of awareness, compassion and action: awareness to recognise those whose wellbeing we can influence, compassion for those in need, and effective action to remedy those needs. For professional engineers such awareness needs to extend well beyond the purely technical aspects of their work.

For example, consider the link between smoking and lung cancer, which might at first appear to be a medical and social issue with no engineering component. At the start of the twentieth century, lung cancer was such a rare disease that medical professors when confronted with a case sometimes told their students that they might never see another. Cigarettes now cause 1.5 million deaths from cancer each year, a number that is expected to rise to nearly 2 million each year by the 2020s or 2030s, even if consumption rates decline in the interim. The cigarette has been described as 'the deadliest artefact in the history of human civilisation' [31]. Technological advances played a very important part in this change.

Up to the end of the nineteenth century, cigarettes were produced by hand with a skilled worker able to produce about 200 in a shift. Such procedures were enough to satisfy a modest demand. This slow production rate was revolutionised by the invention of a mechanically complex but very efficient cigarette-manufacturing machine, as described in two patents [32]. Each new machine could produce 120,000 cigarettes in a day, about a fifth of US consumption at that time [33]. Such technical innovation was followed by huge advertising and marketing campaigns, leading eventually to the present worldwide rate of consumption of about 6 trillion cigarettes each year. Cigarettes were initially promoted as beneficial for health. However, the link to lung cancer was becoming apparent by the 1930s and was clearly established by the 1950s. Cigarette manufacture puts a very low value on human life: 'Cigarette companies make about…US$10,000 for every million cigarettes purchased. Since there is one death for every million cigarettes sold (or smoked), a tobacco manufacturer will make about US$10,000 for every death caused by their products…The value of a human life to a cigarette manufacturer is about US$10,000' [34]. Many causal factors are involved in continuing cigarette use: economic, political, agricultural and so forth. Many different agents are also involved, including farmers, investors, executives, advertisers and retailers.

Engineers now play a key role in the manufacturing process, including the design, manufacture and operation of modern equipment. The largest factory in operation produces 146 billion cigarettes a year (in 2010) and hence probably causes about 146,000 deaths annually [34]. When the technology for rapid cigarette manufacture was invented, the health effects of smoking were not known. However, the engineers now working in the cigarette industry clearly have major ethical issues to address, for they are engaged in what is known to be one of the deadliest of all engineering activities. They may represent only one professional group in the industry, but without their skills the industry could not operate. Those engineers working in the industry may wish to seek alternative employment, for engineering knowledge and skills may be applied for many purposes. Likewise, other engineers seeking employment should ask themselves whether they wish to work in an industry the products of which lead to such dire consequences for so many. Such ethical concerns are especially significant for young engineers, for early employment choices can strongly influence the engineering, and hence ethical, direction of an entire career.

Ethical issues of these types will be considered in the following chapters, including an analysis of the freedom to act that engineers have in such circumstances. It will be found that awareness, compassion and action can be subject to constraints in professional working environments. For example, an official report into the nuclear accident at Fukushima in 2011 found a multitude of errors and instances of wilful negligence, but concluded that the fundamental faults lay in the working culture: 'our reflexive obedience; our reluctance to question authority; our devotion to "sticking with the programme"; our groupism; our insularity' [35]. However, it will also be found that engineers have great opportunities to accept and express ethical responsibility in imaginative ways.

1.5 Outline of the Development in this Book

This book aims to address the greatest challenge to contemporary engineers: *can the great technical innovation of engineering be matched by a corresponding innovation in the acceptance and expression of ethical responsibility?* This challenge will be addressed in four ways;

1. The ethical nature of engineering will be elucidated by making use of key concepts from leading contemporary philosophers.
2. Three ways in which this ethical nature of engineering can be accepted and expressed will be considered: engineering for peace, engineering for health and engineering for development.
3. Ways in which the acceptance and expression of the ethical nature of engineering can be promoted will be considered: the acceptance of personal responsibility and participation in supporting social structures; and convincing others through human rights approaches and the elucidation of engineering power.
4. Future prospects for the acceptance and expression of ethical responsibility will be envisaged.

A Philosophical Analysis of the Nature of Engineering Philosophical analysis of the nature of engineering can be of great benefit in identifying the ethical opportunities and challenges that it offers. The overall nature of engineering will be explored using concepts provided by the work of two leading contemporary philosophers. First, the structure of engineering will be elucidated by considering it as a *practice*, of the type first proposed by Alasdair MacIntyre. This will lead to a description of engineering activities in terms of goals, internal goods, external goods, virtues, institutions and systematic extension. Second, Amartya Sen's concept of *capabilities* will be used to describe the role that engineering can have in promoting both the *wellbeing* and the *agency* of others. Consideration of *agency* is of great benefit in describing an essentially enabling activity such as engineering. Further building on Sen's work, it will be proposed that the idea of an *opportunity of professional capabilities* can guide the development of the ethical aspects of the practice of engineering. It will be suggested that in certain dire circumstances this may become an *obligation of professional capabilities*. Finally, the work of Sidney Loeb, a pioneer of an innovative type of engineering, will be described to illustrate the application of the analysis of the practice of engineering and to provide an example of the fulfilment of an opportunity of professional capabilities.

Engineering for Peace The greatest tragedy of contemporary engineering is the design, manufacture and use of a great diversity of devastating and indiscriminate weapons. Challenging this grave misuse of engineering should be a very high priority for contemporary engineers. A re-evaluation of the contribution of engineering to war and peace will be proposed, building on the analysis of engineering as a practice. This will begin with the incorporation of reliable empirical evidence into an assessment of 'just war' theory. Data show that the victims of recent major wars have been mostly, often overwhelmingly, civilians: there is little evidence of discrimination and proportionality. This situation is so dire as to create for engineers an obligation of professional capabilities to find better use for their skills in the promotion of peace. Furthermore, the requirement of last resort in any commencement of war, a key aspect of 'just war' theory, is especially demanding for engineers, for they possess the knowledge and skills to ameliorate many of the root causes of conflict. Indeed, it is to the amelioration of the root causes of conflict that engineers should direct their attention and efforts. It will be concluded that the logical development of such a reprioritisation is a commitment to use engineering knowledge and skills in *active peacemaking—just engineering*.

Engineering for Health Engineering can make many contributions to the conditions that promote good health, including the provision of clean water and sanitation, buildings that provide shelter and improvements to the effective growth and storage of food. Engineering can also make important contributions to the care that is needed when health fails. Indeed, such contributions are increasingly leading to greater entanglement of the activities of engineers and healthcare professionals. Some key aspects of recent technological innovation in healthcare will be considered: assistive technologies, telehealthcare and quasi-autonomous systems. The ethical challenges and opportunities that arise when such technologies are introduced will be analysed. One of the most attractive opportunities is that such innovation can bring engineers into much closer interaction with the beneficiaries of their work. Furthermore, in such work it is very important to prioritise the agency of beneficiaries.

Another important issue is that engineering activities can in some circumstances have deleterious effects on health, mostly as unintended consequences of otherwise desirable activities. Hence, a further form of entanglement of the activities of engineers and healthcare professionals is the increased awareness in the medical profession of the effects of engineering policy and activities on health. One example of such awareness will be analysed, the effects of transport infrastructure and policy on health. This suggests that transport policy should prioritise *ability to access* and physically *active transport* rather than the ability to travel, hence effectively promoting both the welfare and agency of beneficiaries.

Engineering for Development Billions of people around the world suffer from extreme poverty. Such poverty is characterised by hunger, sickness, lack of shelter and clothing, low incomes, low achievements in education, vulnerability, voicelessness and powerlessness. The causes of such poverty are many, and include political, social, economic and environmental factors. International organisations, governments and non-governmental organisations that are involved in ameliorating such poverty tend to focus on political and economic remedies. However, engineering has a very important role to play for it can provide practical solutions to the needs of people suffering from extreme poverty. As such poverty is a major injustice, it presents a clear case of an opportunity of professional capabilities for engineers. Indeed, as the consequences of such poverty are so appalling, it may better be considered an obligation of professional capabilities for engineers. The role that better provision of energy can play in the amelioration of poverty will be used to provide an example of the nature and magnitude of the issues. Energy is a key enabler: all countries that have moved their populations out of poverty in modern times have done so whilst greatly increasing access to a diversity of energy supplies, replacing human and animal labour with more powerful energy sources. Furthermore, such energy provision requires the collaboration of many different types of engineers, including civil engineers, mechanical engineers, electrical engineers and chemical engineers. It is, therefore, a need to which large numbers of the profession can contribute. Some of the many other ways in which engineering can contribute to the amelioration of extreme poverty will be outlined. The analysis of engineering as an ethical practice will be used to consider how individual engineers and engineering institutions can best contribute to meet such pressing human needs. Finally, some valuable lessons that may be learnt from African approaches to ethics will be considered.

Personal Responsibility and Supporting Social Structures This book proposes an analysis of the ethical nature of engineering and seeks to show how the analysis applies to engineering for peace, engineering for health and engineering for development. However, some academic observers, including a few engineers, have argued that there are a number of reasons why engineers can not in practice truly accept and express ethical responsibility. These arguments will be investigated using an example given by Alasdair MacIntyre and by considering and developing an analysis presented by the philosopher Michael Davis. It will be concluded that the objections are flawed and that engineers really do have opportunities to accept and express ethical responsibility. Nevertheless, engineers are subjected to pressures in their professional life that can make this ethical task difficult. It is therefore of benefit if engineers participate in a base community—a community in which ethical discourse is promoted and in which generous ethical action is stimulated. Two examples of such base communities will be considered: trade unions and faith communities. Two specific cases, the Lucas plan and Benedictine business practices, will be described to show that such base communities can greatly enhance innovation in the acceptance and expression of ethical responsibility in engineering. The Lucas plan shows that engineers are able to make highly innovative proposals that show great prospects for socially beneficial application, sustainable employment and sustainable profitability when they have the motivation and opportunity to think creatively about their work. Benedictine business practices can demonstrably promote technical excellence, ethical engagement and commercial success in a sustainable manner and so provide a real alternative to conventional corporate practice.

Convincing Others—Engineering for Human Rights and Engineering Power Engineers who wish to promote imaginative innovation in the acceptance and expression of ethical responsibility in their profession need to convince others, especially their fellow engineers and decision makers, of the validity and practicality of their ethical vision. Participation in base communities, such as trade unions and faith communities, can promote innovative ethical discourse and generous ethical action in what might be termed a bottom-up approach. It is also important to make use of what might be termed top-down approaches. The first to be considered will be the broad international consensus on the validity and value of human rights. In particular, the recent international application of human rights approaches to business activities provides an important means of expressing the ethical challenges and opportunities for engineers in an universally understood language. Such a human rights approach can be readily understood by business managers and politicians and has the additional advantage of legal backing. The second approach to be considered will aim more specifically to find a means of convincing Western politicians of the scope for engineering to contribute to human flourishing. This is a difficult task as most leading Western politicians have a very poor knowledge of the nature of engineering. Based on the writings of a leading ethically engaged twentieth century politician, Aneurin Bevan, and a leading political theorist, Joseph S. Nye, it will be suggested that the best way to communicate with politicians is to use the language of political power. Engineering can be both a power resource and a means of power conversion and hence of realising power. Extending Nye's concepts of soft power, smart power and relational power, it will be proposed that engineers should engage politicians through discussion of *engineering power*, the ability to attain preferred outcomes though the peaceful use of engineering capabilities.

Future Perspectives The final chapter will be concerned with the future prospects for increasing the acceptance and expression of ethical responsibility by engineers, particularly in an extended time frame. Each of the themes of the preceding chapters will be addressed followed by consideration of some underlying issues. The key suggestions will include:

- Broadening of the intellectual basis of engineering education.
- Inclusion of the promotion of peace as an internal good of engineering.
- Seeking close cooperation with other professionals, particularly in healthcare.
- Engagement with UN initiatives beyond the Millennium Development Goals.
- Promotion of business models that promote the ethical practice of engineering.
- Increased involvement of engineers in social and political movements.

Most important of all, the future ethical practice of engineering requires the acceptance and expression of responsibility by every engineer.

Appendix

Royal Academy of Engineering *Statement of Ethical Principles*

The Royal Academy of Engineering, in collaboration with Engineering Council (UK) and a number of the leading professional engineering institutions, has created a Statement of Ethical Principles to which it believes all professional engineers and related bodies should subscribe.

Professional Engineers work to enhance the welfare, health and safety of all whilst paying due regard to the environment and the sustainability of resources. They have made personal and professional commitments to enhance the wellbeing of society through the exploitation of knowledge and the management of creative teams.

This Statement of Ethical Principles sets a standard to which members of the engineering profession should aspire in their working habits and relationships. The Statement is fully compatible with the principles in the UK Government Chief Scientific Adviser's Universal Ethical Code for Scientists, with an emphasis on matters of particular relevance to engineers. The values on which it is based should apply in every situation in which professional engineers exercise their judgement.

There are four fundamental principles that should guide an engineer in achieving the high ideals of professional life. These express the beliefs and values of the profession and are amplified below.

Accuracy and Rigour

Professional Engineers have a duty to ensure that they acquire and use wisely and faithfully the knowledge that is relevant to the engineering skills needed in their work in the service of others. They should:

- always act with care and competence.
- perform services only in areas of current competence.
- keep their knowledge and skills up to date and assist the development of engineering knowledge and skills in others.
- not knowingly mislead or allow others to be misled about engineering matters.
- present and review engineering evidence, theory and interpretation honestly, accurately and without bias.
- identify and evaluate and, where possible, quantify risks.

Honesty and Integrity

Professional Engineers should adopt the highest standards of professional conduct, openness, fairness and honesty. They should:

- be alert to the ways in which their work might affect others and duly respect the rights and reputations of other parties.
- avoid deceptive acts, take steps to prevent corrupt practices or professional misconduct, and declare conflicts of interest.
- reject bribery or improper influence.
- act for each employer or client in a reliable and trustworthy manner.

Respect for Life, Law and the Public Good

Professional Engineers should give due weight to all relevant law, facts and published guidance, and the wider public interest. They should:

- ensure that all work is lawful and justified.
- minimise and justify any adverse effect on society or on the natural environment for their own and succeeding generations.
- take due account of the limited availability of natural and human resources.
- hold paramount the health and safety of others.
- act honourably, responsibly and lawfully and uphold the reputation, standing and dignity of the profession.

Responsible Leadership: Listening and Informing

Professional Engineers should aspire to high standards of leadership in the exploitation and management of technology.

They hold a privileged and trusted position in society, and are expected to demonstrate that they are seeking to serve wider society and to be sensitive to public concerns. They should:

- be aware of the issues that engineering and technology raise for society, and listen to the aspirations and concerns of others.
- actively promote public awareness and understanding of the impact and benefits of engineering achievements.
- be objective and truthful in any statement made in their professional capacity.

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Chapter 2
A Philosophical Analysis of the Nature of Engineering

2.1 Introduction

Some philosophical analysis of the nature of engineering can be of great benefit in identifying the ethical opportunities and challenges that it offers. This chapter will explore the overall nature of engineering using concepts provided by the work of two leading contemporary philosophers. First, the structure of engineering will be elucidated by considering it as a *practice*, of the type first proposed by Alasdair MacIntyre. Secondly, Amartya Sen's concept of *capabilities* will be used to describe the role that engineering can have in promoting both the *wellbeing* and the *agency* of others, and further to propose an *opportunity of professional capabilities* that can guide the development of the ethical aspects of the practice of engineering. Finally, the work of Sidney Loeb, a pioneer of an innovative type of engineering, will be described to provide a first illustration of how the analysis developed may be applied.

2.2 The Practice of Engineering

MacIntyre uses the term *practice* to describe a certain type of 'coherent and complex form of socially established cooperative human activity'. He gives a very specific definition of what he means by a practice:

> …any coherent and complex form of socially established cooperative human activity through which goods internal to that form of activity are realised in the course of trying to achieve those standards of excellence which are appropriate to, and partially derivative of, that form of activity, with the result that human powers to achieve excellence and human conceptions of the ends and goods involved are systematically extended [1].

Among his examples of practices are: games such as chess and football; artistic endeavours such as portrait painting and music; intellectual enquiries such as the sciences and history; and activities such as farming, commercial fishing and architecture [2]. Consideration of this diverse list has led Miller to propose a very

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useful distinction between 'self-contained' practices and 'purposive' practices [3]. Games are the clearest examples of self-contained practices, for here it is the activity of the game itself that is of paramount importance. In contrast, purposive practices have arisen to serve social ends beyond themselves. Thus, the social ends of the purposive practices of farming and commercial fishing are the production of food, and the social end of architecture may be considered to be the creation of functional and aesthetically pleasing buildings.

Neither MacIntyre nor Miller gives attention to engineering, but considering engineering as a practice can be very helpful in developing an ethical analysis of its activities [4]. It is clear that in Miller's terms engineering is a purposive practice. An account of the nature of engineering can hence be developed by considering the key features of a purposive practice. Following MacIntyre, these may be considered to be: (i) the end or goal; (ii) internal goods; (iii) external goods; (iv) virtues or principles; (v) institutions and (vi) systematic extension. Each of these features will now be given some preliminary consideration.

2.2.1 End or Goal

It is difficult to devise a succinct statement of the goal of an activity as diverse as engineering.[1] Any brief statement will require further elucidation. It has been noted in Chap. 1 that the UK Royal Academy of Engineering describes what in Miller's terms are the purposive social ends of engineering as being 'to enhance the welfare, health and safety of all whilst paying due regard to the environment and the sustainability of resources' [5]. This has the benefit of being an ambitious statement, as is appropriate for the expression of an overall goal. However, it could benefit from further development and elucidation.

Hence, as a working definition, it is proposed to describe the goal of engineering as being *the promotion of the flourishing of persons in communities through contribution to material wellbeing*. Here the expression 'flourishing' is intended to convey a richer contribution to human life than welfare, health and safety. As will be made clearer later, flourishing includes not only wellbeing but also the agency of persons in communities. This is particularly important for an enabling activity such as engineering. The expression 'persons in communities' provides a starting point for the elucidation of 'all'. First, it recognises that though engineering is concerned with promoting the wellbeing of communities, it is also concerned with promoting the wellbeing of each individual person in those communities. Hence, great care and discernment will be needed if engineering activities lead to potential conflict between the wellbeing of communities and the wellbeing of some of the persons of which they are comprised. Second, the term 'communities' is taken to include cooperative social groupings of all sizes,

[1] Engineers use the term 'goal' to describe what a philosopher might term an 'end'.

including cooperation beyond the boundaries of nation states or close political alliances, at which societies tend to draw their limits. Third, as communities have a history and a future that extends well beyond the lifetime of any individual person, this definition implies a commitment to both social and environmental sustainability. Furthermore, the expression ‘through contribution to material wellbeing’ provides a starting point for describing the specific means by which engineering seeks to promote human flourishing. These involve the use of science and mathematics combined with reason, imagination, judgement and experience.[2] Consideration of the internal and external goods of engineering will make these means clearer.

2.2.2 Internal Goods

The purposive practice of engineering seeks to benefit persons and the communities in which they live. However, it is not an ascetic activity. Indeed, there are certain goods which not only require knowledge of the practice for specification but which are also best, or in some cases only, recognised by and available to those participating in the practice. These goods characteristically benefit all participants in the practice, and in some cases also all those affected by the practice. MacIntyre terms these internal goods.

Many of the internal goods of engineering are particularly associated with technical excellence. Some of these are subjective. Engineering characteristically involves the imaginative and practical use of science and mathematics. Thus, the practising engineer directly experiences certain goods, such as the satisfaction of finding an elegant mathematical formulation of an engineering problem or the intellectual reward arising from the development of an ingenious practical solution in the design of an innovative piece of equipment. Such excellence becomes objective when it is recognised by other practitioners. There may often be broad consensus among engineers as to what constitutes such engineering excellence, though expectations and standards will develop with time.

The goal of the promotion of the flourishing of persons in communities through contribution to material wellbeing is associated with certain characteristic internal goods that are broader in scope.[3] Thus, all engineers give great priority to safety: the safe operation of products and processes is of paramount importance in engineering practice. However, as no human activity is entirely free of risk, the assessment of safety and balancing of benefits and risks is challenging. Quantification of safety and risks is very important, but qualitative public perceptions also need to be taken into account. Cost-effectiveness is an another important internal

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[2] Engineering also facilitates science in many ways, the largest scale example being the Large Hadron Collider (LHC) at the European Organisation for Nuclear Research (CERN).

[3] I thank Jon A. Schmidt for emphasising this point to me.

good of which all engineers are continually aware. This can be a significant feature of safety assessments, but has a broader significance in bringing the benefits of engineering to as many persons and communities as possible. Furthermore, as already noted, social and environmental sustainability are such central concerns of engineering that they feature in almost all engineering activities and may be considered internal goods in this wider sense.[4] In Chap. 7 a case will be made for considering the promotion of human rights as an internal good of engineering. In Chap. 8 it will be proposed that the pursuit of peace should be regarded as such an internal good.

Finally, it is important to note what is for many engineers the greatest subjective internal good of all: the satisfaction of contributing to the flourishing of persons in communities. This provides a strong intrinsic motivation for the work of engineers. Indeed, intrinsic motivations of this type can be stronger than tangible external rewards for they change the character of the activity [6]. It is in such a way that an ethical approach to engineering can promote the quest for technical excellence. This may be particularly apparent when the engineer and beneficiaries are in close proximity.

2.2.3 External Goods

MacIntyre's characteristic examples of external goods are prestige, power and wealth. It is distinctive of such goods that they are the property or possession of an individual or group, and that they are typically achieved in competition, resulting in losers as well as winners. Goods such as these are often contingently attached to practices and could, in principle, be achieved in other ways. However, purposive practices also give rise to external goods that are specific to their activities, such as fish in the case of commercial fishing and buildings in the case of architecture.

The practice of engineering gives rise to considerable economic benefits for the communities in which its activities take place. Countries with innovative and productive engineering sectors are noted for their economic strength and stability. Also, as engineering is not as ascetic activity, engineers themselves derive significant financial rewards for their work. Indeed, this is an important extrinsic motivation for the work of engineers. Engineers may attain a certain prestige on account of their profession, and a few may even become famous. However, power is not usually considered to be an external good of engineering, at least in a political sense.[5]

[4] For this reason, the goal of engineering should be understood as 'the promotion of the flourishing of persons in communities *in an environment* through contribution to material wellbeing'. However, this is left implicit as persons and communities are always in an environment. The importance of several types of environment will feature in later chapters, including work environments, social environments, built or engineered environments and natural environments.

[5] This view is challenged in Chap. 7.

Rather, the most obvious characteristic external goods of engineering are technological artefacts, the many products and processes on which modern society depends. As noted in Chap. 1, among the most beneficial are clean water production and sanitation, energy generation, large-scale pharmaceutical manufacture, hygienic food processing, transport infrastructure, mechanical devices, medical diagnostic equipment, instrumentation, computing and telecommunications.

It will be noted that many of these technological artefacts not only contribute to human wellbeing (such as welfare, health and safety) but also enable others to choose the type of life they wish to live. Hence, it can be appropriate to consider further the external benefits of engineering in terms of Sen's concept of *capabilities*, the various things that a person manages to do or be in leading a life [7, 8]. Such capabilities he describes in terms of both *wellbeing* and *agency*, the latter being the possibility to advance whatever goals and values a person has reason to advance. Wellbeing is particularly useful in assessing issues of distributive justice. Agency gives attention to the person as a doer. The specific inclusion of agency allows for a much richer description of benefits than consideration of wellbeing alone. For example, a person may have reasons for pursuing goals other than personal wellbeing or individual self-interest, including promoting the wellbeing of others and respect for their agency.

Sen further characterises wellbeing and agency in terms of *achievement* and *freedom*. Freedom refers to a person's options and opportunities, and may have a plurality of expression, including basic aspects such as freedom from hunger and higher level aspects such as developing self-respect or creative fulfilment. He notes that such freedom has not only instrumental but also intrinsic value, and may be directed to the benefit of others.

Taken together, this analysis yields four concepts of benefit to a person: (i) *wellbeing achievement*; (ii) *agency achievement*; (iii) *wellbeing freedom*; (iv) *agency freedom* [9]. This fourfold classification of advantages seems particularly useful for thinking about the external goods of the essentially *enabling* activity of engineering. Furthermore, the approach is general enough to allow for a great range of specific circumstances. For example, persons in poorer communities may particularly benefit from provision of necessary basic goods, such as clean water and sanitation. These may already exist in wealthier communities, where wellbeing and agency may be further advanced by additional consideration of how further benefits, such as cultural goods, are provided. In all circumstances, wellbeing and agency are important aspects of human flourishing.

It is worth emphasising a key effect of considering capabilities as external goods of engineering: attention is moved from engineering as the provider of physical artefacts to the effects of engineering on the lives which people are able to lead. That is, consideration of capabilities promotes an emphasis on the ethical nature of the practice of engineering. As will become clear in later chapters, the consequent consideration of both wellbeing and agency changes priorities in engineering. An emphasis on engineering as a provider of physical artefacts leads to engineers posing questions of the form 'what kind of technology can best meets the needs of a person or community?'. In other words, consideration of what can be *done for* the person or community, placing the person or community in a passive role. A consideration of capabilities additionally asks 'what can the person or community *do*?', acknowledging that the person or community can be active contributors to their flourishing. Furthermore, although engineering can have a great influence on such flourishing, engineers need to maintain modesty about their contribution. As one of the pioneers of ethical approaches to engineering in the UK, Meredith Thring, has eloquently observed, each engineer must realise that '*the subjective qualities of human life, such as self fulfilment, happiness, inner freedom, and love, have much more real long-term importance to the people affected by his [or her] engineering than does the possession of goods and status symbols beyond those necessary for a full life*' [10].

It should be borne in mind that there is not always a sharp distinction between internal goods and external goods. Thus, safety, cost-effectiveness and social and environmental sustainability have here been considered internal goods of the practice of engineering. However, their specific instantiations are clearly of benefit to others and hence comprise external goods of the practice. As a contrary example, some features of external goods, such as ingenious features of technological artefacts, may only really be appreciated by engineering practitioners even though the artefacts as a whole are of great benefit to others.

2.2.4 Virtues or Principles

According to MacIntyre, a virtue is 'an acquired human quality the possession and exercise of which tends to enable us to achieve those goods which are internal to practices and the lack of which effectively prevents us from achieving any such goods' [11]. He regards such virtues as defining the relationships between people who share the purposes and standards of a practice. He further regards truthfulness, justice and courage as being prerequisite virtues for any practice, providing the following explanation for the somewhat unexpected inclusion of courage: 'We hold courage to be a virtue because the care and concern for individuals, communities and causes which is so crucial to so much in practices requires the existence of such a virtue' [12]. All of this is very relevant to the practice of engineering, but it is necessary for such a purposive practice to extend the definition of a virtue beyond the enabling of the achievement of internal goods to include also the achievement of external goods and goals.

Furthermore, it is possible to identify certain desirable human qualities that are particularly appropriate for the practice of engineering. As noted in Chap. 1, the Royal Academy of Engineering has identified four such 'fundamental principles' that should guide engineers in achieving the high ideals of professional life: *accuracy and rigour*; *honesty and integrity*; *respect for life, law and the public good*; *responsible leadership, listening and informing* [5]. Though these principles may be applied throughout a professional engineer's activities, they are each particularly relevant to differing aspects of his or her work. Thus, *accuracy and* *rigour* are especially relevant to the purely technological aspects of such work, in particular the application of mathematics, scientific knowledge, and practical know-how. The importance of technological competence is strongly emphasised. The requirement for *honesty and integrity* becomes particularly relevant in the business dealings of engineers. This can be challenging for an international activity such as engineering, for acceptable business standards can vary greatly between different cultures. *Respect for life, law and the public good* is an essential recognition of the profound effects which engineering can have on the flourishing of individuals and the communities in which they live. Proper expression of such respect can demand great care, for the effects of an engineer's activities may have consequences that are very extensive in both place and time. The need for *responsible leadership, listening and informing* arises from the privileged and trusted position in society that results from engineers' specific and high-level expertise. They not only have knowledge and skills which enable the solving of problems and the fulfilment of opportunities, but even more importantly the same knowledge and skills may provide them with an unique ability to identify such problems and opportunities. Thus, it is these four principles which have been recognised as being most important for the specific fulfilment of the practice of engineering. In MacIntyre's terminology they may be considered virtues. The text in the Appendix of Chap. 1 provides further details of how each principle or virtue is to be understood.

Virtues have so far here been considered in the context of the practice of engineering. However, MacIntyre also highlights a specific feature of his view of virtues: 'no quality is to be counted a virtue except in respect of its being such as to enable three distinct kinds of goods: those internal to practices, those which are the goods of an individual life and those which are the goods of community' [13]. The reference to an individual life is important in the present context as it recognises the significance for each individual of achieving continuity and coherence in both professional and personal life [14]. We are human persons always and only sometimes engineers. Such consideration can provide a useful check on the ethical validity of professional activities. The reference to the community is met in the present context by considering virtues as enabling the goal of the practice of engineering.

2.2.5 Institutions

For MacIntyre, no practice can survive for an extended period of time unless it is sustained by institutions, of which he gives clubs, laboratories and universities as examples. Institutions provide an historic dimension, sustaining the continuity and coherence of a practice. Among the important institutions of the practice of engineering are regulatory authorities, university departments, professional associations and commercial enterprises.

The national regulatory authority in the UK for the registration of professional engineers is the Engineering Council. The key professional designation that it awards is Chartered Engineer (CEng). Achievement of this designation typically requires, at a minimum, successful completion of an accredited, 4-year Master of Engineering (MEng) (Hons) university degree course, a subsequent 4-year period of training and work experience, and the holding of a sufficiently responsible position in engineering. The present book uses the term ‘engineer’ in this rigorous professional sense, and the term ‘engineering’ is used to describe the endeavours of such professionals. Such precision is important, for insufficient clarity in the use of these designations and other terms such as technologist, technology, scientist and science is a source of much confusion in society.

Thus, engineers enter the profession through university level education. If engineering is to continue contributing to human flourishing, it is essential to recruit technically able and highly motivated young people with a desire to help others. University engineering courses give high priority to technical competence and require a high level of scientific and mathematical ability for successful completion. However, courses increasingly also include education in engineering ethics, often termed professional responsibility, and substantial effort has been invested recently in providing a focus on ethics as an inherent part of professional engineering activities. Nevertheless, university engineering departments face a challenge in recruiting sufficient numbers of technically competent and ethically sensitive students, as the contribution of engineering to human flourishing may be poorly appreciated by young people. In addition to providing education, university engineering departments help sustain the practice of engineering by being centres of excellence in engineering research, often initiating the research from which the practical innovations of the future derive.

Engineering has a diverse range of professional associations. In the UK,[6] for example, the national academy of engineering is the Royal Academy of Engineering, which fulfils roles comparable to those of the Royal Society in science and the British Academy in humanities and social sciences. The Academy seeks to enhance national engineering capabilities, recognise excellence, inspire the next generation of engineers and lead debate concerning public policy making about engineering. Additionally, there are 36 professional associations representing various sub-disciplines of engineering in the UK, a complexity that has arisen for historical reasons. A few are large, such as those representing civil engineering, mechanical engineering and chemical engineering, and many are small. These make important contributions to sustaining the profession through promoting standards of excellence, improving public understanding of engineering and providing support to both individual engineers and engineering employers.

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[6] This paragraph refers to the UK, but comparable professional associations exist in many countries.

Commercial engineering enterprises lie at the core of the practice's ability to provide the material artefacts that promote the flourishing of persons in communities. Some of these enterprises are large multinational organisations employing thousands of engineers as well as many other types of staff. However, in the UK and the rest of Europe there has been a decline in large industries and a growth in more specialised companies, small and medium enterprises (SMEs), leading to changing employment opportunities for engineers. For example, chemical engineers are now less likely to find employment in petrochemical industries and are increasingly likely to work in businesses operating on a more modest scale in areas such as food processing or environmental protection. As employees in commercial organisations, engineers may experience a conflict between their professional values and the requirements of their employers, for commercial organisations are characteristically most concerned with external goods, particularly profit. Resolving such a conflict may require great discernment. However, organisations also exist that specifically aim to take person and community centred approaches to engineering that reach beyond technical issues. For example, Engineers Against Poverty [15], a specialist organisation working in the field of international development, aims to use the skills and resources of the private sector to secure social improvements through mechanisms that also deliver commercial advantages to the companies involved.

2.2.6 Systematic Extension

An important feature of practices is that through such activities the 'human conceptions of the ends and goods involved are systematically extended' [1]. The most familiar extension of the practice of engineering is the continual development of sophisticated engineered artefacts. Indeed, improving the technical aspects of engineering can bring great satisfaction to practitioners. However, this leads to the danger of becoming so absorbed in the technical aspects that the ethical dimension, the effect of the technology on others, is neglected or lost. The avoidance of this danger can be stated as a positive challenge to engineers: *can the great technical innovation of engineering be matched by a corresponding innovation in the acceptance and expression of ethical responsibility?* The present book is especially concerned with exploring the systematic extension of engineering in such ethical terms.

In this context, it is important to emphasise that a successful practice pays appropriate attention to *all* of its key constituent features. A cautionary note is required here. MacIntyre identified the dangers of too great a focus on external goods such as wealth, fame or power. We are all familiar from news media of the disastrous consequences of the reckless pursuit of such goods. In the case of engineering there is an additional and particular danger of focusing too greatly on the external goods of technological artefacts. Too great a prioritisation of the development of technically ingenious artefacts can lead to mistaking the external goods of the practice for the real end of the practice. Furthermore, it might even be possible for a practice to become so distorted in its goods and ends that it should be considered perverse or even evil: it has been suggested that torture may be such a practice [16]. Issues of the distortion and perversion of the practice of engineering will be considered later. For the present, it will be noted that MacIntyre's approach considers goods not only as they are connected with a practice, but also as they contribute to the flourishing of the whole lives of those participating in the practice and the flourishing of the broader community affected by the practice. That is, an individual person's life should have an overall coherence and a community's range of practices should harmonise.

2.3 An Opportunity of Professional Capabilities

The goal of engineering has been described as *the promotion of the flourishing of persons in communities through contribution to material wellbeing*. This is expressed in very general terms, as is appropriate for an activity as diverse as engineering. Individual engineers and engineering institutions may seek to contribute to the fulfilment of this goal in many different ways. Their actions will typically involve practical improvements to presently existing circumstances, using their unique engineering capabilities to identify and implement such improvements. If engineers are to seek real innovation in the acceptance and expression of ethical responsibility, it can be beneficial to have an aspirational approach to the prioritisation of such activities. It may be proposed that a useful guide for the choice of such actions can be formulated in terms of an *opportunity of professional capabilities*:

> …if some action that can be freely undertaken is open to a person (thereby making it feasible), and if the person assesses that the undertaking of that action will create a more just situation in the world (thereby making it justice-enhancing), then that is argument enough for the person to consider seriously what he or she should do in view of these recognitions.

This formulation was used to define an *obligation of power* in Sen's account of political justice [17]. However, engineers rarely have the type of political power referred to by Sen. It is, therefore, proposed here to retain the definition but to refer instead to an *opportunity of professional capabilities*. Such opportunity could be considered as a generalisation of the 'rule of rescue': the compelling motivation to save endangered human life wherever possible. When we become aware of the need of others we are almost always free to walk away. Nevertheless, we are often moved to action by the challenge that confronts us. Such action is an ethical act, 'a response to the being who in a face speaks to the subject and tolerates only a personal response' [18], as was discussed in Chap. 1.

It should also be noted that this opportunity is practical rather than idealistic, for it concerns the serious consideration of feasible options and thus recognises that there may be situational constraints on the action (at least initially). The *opportunity* certainly refers to a type of situation in which many engineers may find themselves, for they have at their disposal a range of knowledge, skills, techniques and technologies of great potential. Most importantly, as noted previously, the same knowledge and skills may provide them with an unique ability to identify such problems and opportunities. The term *capabilities* has already been introduced as referring to the various things that a person manages to do or be in leading a life, including *agency*, the possibility to advance whatever goals and values a person has reason to advance. That is, agency gives attention to the person as a doer. Here the term *professional capabilities* is taken to refer specifically to the professional actions which an engineer can undertake to remove injustice and to promote justice.

An *opportunity of professional capabilities* can provide powerful motivations for seeking to promote the flourishing of persons in communities. In particular, it can help guide the systematic extension of the practice of engineering in ethical terms. It is consonant with both engineering and Sen's approach to ethics, each of which seeks to further *practically* the wellbeing and agency of persons in whatever circumstances they find themselves. Furthermore, it will be argued in later chapters that sometimes the circumstances of persons and communities may be so dire, and the capabilities of engineers so apt, that it is more appropriate to consider an *obligation* of professional capabilities.

However, it will be helpful at this point to illustrate how the analysis presented so far may be applied. Thus, the next section considers the activities of a pioneer of an innovative type of engineering.

2.4 Sidney Loeb: His Engineering Work and an Ethical Analysis

In the second part of the last century, there was an urgent need to find ways of producing drinking water from saline water. Sidney Loeb's[7] paradigmatic contribution to meeting this need began with his work on a technical problem. Separation from liquids of small entities such as colloids, macromolecules and simple ions (salts) may be achieved using a type of advanced filter known as a membrane that contains appropriately sized pores, typically in the range 100 nm to less than 1 nm (a simple ion is typically ~0.5 nm in diameter in solution).[8] This raises a number of initial technical issues, two of the most important being: (i) How can large areas of membrane containing such tiny pores be fabricated? (ii) As the

[7] Engineers among the readers of this book may have had the pleasure of knowing Sidney Loeb, who died aged 91 in December 2008. The outline of his work given here is provided for those unfamiliar with his achievements.

[8] One nanometre (nm) is one thousand millionth of a metre (10^{-9} m).

hydraulic resistance of a pore increases very rapidly with decreasing size,[9] how can a practically useful membrane be fabricated?

The key to solving these and other issues was the invention in 1959 by Loeb and Srinivasa Sourirajan of polymeric anisotropic membranes, that is, polymer membranes in which a thin porous layer (say ~1 μm thick)[10] with the required separation properties was supported on a thicker layer with much larger pores. If such a structured membrane (comprising both layers) is then itself appropriately supported, it can withstand the high pressures (up to as much as 80 atmospheres in some cases) required to force purified water through the pores whilst retaining salt. By such means, salt may be removed from water at a useful rate, thus allowing the production of drinking water from brackish water and even from seawater. The first Loeb and Sourirajan membrane was what is now termed a reverse osmosis membrane, and is the prototype of a family of membranes, also including nanofiltration membranes and ultrafiltration membranes, with pores in specified segments of the range from sub-nanometre dimensions to about 100 nm.

Sidney Loeb was known as a man of great ethical integrity, much concerned about human flourishing. He was thus motivated to play a key role in applying his invention through the development of the world's first commercial reverse osmosis system in the town of Coalinga in California, a development that required the ingenious solution of several practical engineering problems. The process at Coalinga provided 19,000 l of drinking water daily for the residents; there was a special need for such provision as the local water was so high in minerals that drinking water was previously transported in by rail tanker. He subsequently moved to Israel, and worked on that country's first reverse osmosis plant at Kibbutz Yotvata, which used locally manufactured membranes to produce 150,000 l of drinking water daily. This installation was important as the local water was sufficiently brackish to pose a serious threat to health when consumed. Throughout his life, he continued to support the commercialisation of membrane-based water treatment processes throughout the world.

The reverse osmosis business that Sidney Loeb pioneered is now worth many billion euros annually. Installed reverse osmosis processes produce in excess of 13.5 billion cubic metres of drinking water annually and are now the leading desalination technology on a world basis. Additionally, more than 17,000 small industrial, ship-mounted and household reverse osmosis systems are also in use. Furthermore, the closely related processes of nanofiltration and ultrafiltration are very widely used throughout the manufacturing industries, including pharmaceuticals and food production. Such membrane processes also have important medical applications.

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[9] Assuming constant fluid viscosity, hydraulic resistance is directly proportional to the length of a pore and proportional to $(1/\text{pore diameter})^4$. A further increase occurs due to the increased viscosity of water in pores of nanometre dimensions.

[10] One micrometre (μm) is one millionth of a metre (10^{-6} m).

It is now possible to consider Sidney Loeb's work in the philosophical framework described earlier. Thus, in terms of MacIntyre's description of a *practice*:

End/Goal—Sidney Loeb made clear in many conversations, lectures and actions that he was motivated by a compassionate concern for the flourishing of those within his community and outside the boundaries of that community.

Internal goods—Discovery (with Srinivasa Sourirajan) and recognition of the importance of membranes with an anisotropic structure; ingenious solution of practical engineering problems in the design, cost-effective construction and safe operation of the world's first commercial reverse osmosis plant at Coalinga in California.

External goods—Successful construction and operation of the plant at Coalinga and the subsequent plant at Kibbutz Yotvata, both meeting essential local needs; continued support for commercialisation of membrane-based water treatment processes to billion-euro status.

Virtues—The key engineering virtues were apparent throughout the development of this work: accuracy and rigour; honesty and integrity; respect for life, law and the public good; responsible leadership, listening and informing.

Institutions—Many have arisen to support the practice: research centres (including Srinivasa Sourirajan's), technical journals and commercial companies.

Systematic extension—Development of all of the key features of this part of the practice of engineering continues. An important current priority is the development of low cost systems for impoverished communities.

Further examples of the benefits to persons, external goods, may be made clear in terms of Sen's concept of *capabilities*:

Wellbeing achievement—Improved health due to the provision of high-quality drinking water.

Agency achievement—Improved health allows adults to take a fuller part in society and ensures that children are well enough to attend and fully benefit from school: these are just an indication of a multitude of such benefits.

Wellbeing freedom—Benefits continue to increase as membrane engineering provides for the growing worldwide need for high-quality water—much of the world's population lives within a few kilometres of the sea which thus provides an accessible large resource.

Agency freedom—Options and opportunities continue to arise due to the use of membranes in a multitude of processes including pharmaceutical and food production.

Thus, MacIntyre's and Sen's concepts provide a good framework for the consideration of the engineering development of membrane desalination and related membrane processes. The *agency* benefits are particularly worthy of attention as these are often neglected in ethical assessment of engineering. It should also be noted that Sidney Loeb's work was quintessentially that of an engineer. If he had been a scientist, he might have been content with acquiring further knowledge of the properties of anisotropic membranes. If he had been a technologist, he might have been content with the invention of ingenious laboratory devices incorporating such membranes. However, as an engineer he acted on what we could now express as an *opportunity of professional capabilities*. His success shows that aspirational approaches of this type are practically achievable. Furthermore, he received the benefit of an immensely rewarding subjective internal good, in the words of an appreciation in the *Jerusalem Post*, 'he enjoyed the satisfaction of knowing that he had contributed so much to the welfare of so many, now and in generations to come' [19].[11]

Appendix

Engineering, Technology and Science; Engineering, Medicine and Psychology

In Chap. 1, it was noted that it is important to be aware of the different natures of engineering and technology. It can be also be beneficial to be aware of the different natures of engineering and science. Although engineering, technology and science are most usually characterised on anthropological, epistemological or sociological grounds [21], the concept of a practice allows the suggestion of a philosophical distinction.

Thus, for the case of the engineer, it may be suggested that goals, internal goods and external goods are all important and distinct. For the case of the technologist, it may be suggested that goals and external goods tend to converge (for example, the creation of a technically ingenious device). For the case of the scientist, it may be suggested that goals and internal goods tend to converge (for example, the discovery that results in publication in a prestigious journal such as *Nature*). Such philosophical distinctions are not exact, but they may be considered to identify trends that help clarify confusions.

It may also be helpful to observe that the ethical practice of engineering is closer to the practice of medicine than to the practice of psychology. For example, although medical complicity in torture exists, physicians are reported to have had a more limited involvement than have psychologists in the 'enhanced' interrogations

[11] For further details of Sidney Loeb's life and work see [20].

at the US prison at Guantanamo Bay.[12] Indeed, the chair of the American Medical Association (AMA) council on ethical and judicial affairs has advised, ‘Physicians must not conduct, directly participate in, or monitor an interrogation with an intent to intervene, because this undermines the physician’s role as a healer’. In contrast, the American Psychological Association (APA) has taken the view that such an interrogation is a psychological endeavour in which psychologists may have a special role to play, ‘Psychology is central to this process because an understanding of an individual’s belief systems, desires, motivations, culture and religion likely will be essential in assessing how best to form a connection and facilitate educing accurate, reliable and actionable intelligence’. Again, whereas the AMA campaigns against tobacco use due to the dire effects on health, the APA has taken the view that cigarettes are ‘one of a number of products considered to be hazardous’.

The ethical practice of engineering is committed to enhancing the ‘welfare, health and safety of all’, or otherwise expressed, to promoting the *flourishing of persons in communities*. As a consequence, engineers should be advised not to participate in the design, manufacture and use of equipment for torture or, as discussed in Chap. 1, to participate in the design, manufacture and use of cigarette manufacturing equipment. Such advice is consonant with that given to medical professionals.

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Chapter 3
Engineering for Peace

> The reader may perhaps wonder, as I now myself, that knowing the state of the vile traffic to be as I have here described, and abounding with enormities which I have not mentioned, I did not at the time start with horror at my own employment as an agent in promoting it. Custom, example and interest had blinded my eyes [1].

3.1 Introduction

The greatest tragedy of contemporary engineering is the design, manufacture and use of a great diversity of devastating and indiscriminate weapons. Challenging this grave misuse of engineering should be a very high priority for contemporary engineers. This chapter will build on the analysis of engineering as a practice presented in Chap. 2 to re-evaluate the contribution of engineering to war and peace. This will begin with the incorporation of reliable empirical evidence into an assessment of 'just war' theory. Data show that the victims of recent major wars have been mostly, often overwhelmingly, civilians: there is little evidence of discrimination and proportionality in the conduct of modern wars. Furthermore, the requirement of last resort in any commencement of war, a key aspect of 'just war' theory, is especially demanding for engineers, for they possess the knowledge and skills to ameliorate many of the root causes of conflict. Hence, much greater attention should be directed to the practical use of engineering resources to avert war. It will be concluded that the logical development of such reprioritisation is a commitment to use engineering knowledge and skills in *just engineering—active peacemaking*.

W. R. Bowen, *Engineering Ethics*, DOI: 10.1007/978-3-319-04096-7_3,

3.2 Victims of Engineering

In November 2010, two sisters, Paeng, aged 15, and Piou, aged 10, were returning from school in central Laos when the younger girl picked up a small object to show her sister. She then threw it to the ground where it exploded. Both girls were taken to hospital in the capital, 3 h away. The younger girl bled to death 30 min after arrival in hospital. Her sister had severe fragmentation wounds in her neck, hand and hip [2].

The younger sister had picked up a cluster munition bomblet, probably dropped by US forces more than 30 years before.[1] The design of these submunitions is such that many cause immediate and indiscriminate injury and death, but others remain unexploded until subsequently disturbed. These quiescent submunitions, which are small and often brightly coloured, are especially attractive to children. They have caused the injury and death of tens of thousands of civilians. The death of Piou and the severe injuries sustained by Paeng were typical for these weapons, but their case was especially poignant as it occurred whilst the first meeting of states party to the Convention on Cluster Munitions (CCM), which prohibits all use, stockpiling, production and transfer of such weapons, was taking place in Vientiane, also in Laos.

The design, manufacture and use of cluster munitions require the application of sophisticated engineering across the range of the discipline. Hence, in a real sense, Paeng and Piou were victims of engineering. They were two of the many such victims, for the greatest tragedy of the engineering profession is that during the twentieth and early twenty-first centuries generations of the most able engineers have worked on the development, manufacture and use of many types of weapons of indiscriminate effect and huge devastation potential. War has become the normal business of engineering: almost a third of engineers in the US are employed in military-related activities [4] and the largest single employer of engineers in the UK is an arms-producing company. The resources used are enormous, world military expenditure was at least US$1738 billion in 2011, with weapons sales exceeding US$411 billion [5].[2]

Such military engineering can be accompanied by an astonishing degree of ethical detachment on the part of individuals, commercial engineering enterprises and professional engineering associations. At the individual level, a leading exponent of 'nuclear deterrence' in the UK has described that issue as 'intellectually congenial perhaps because of its combination of complexity and

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[1] A cluster munition is a means of delivering and scattering a large number of explosive submunitions (bomblets). A single cluster munition may scatter submunitions over an area of 1 km^2. The number of submuntions delivered may be enormous: during the 1991 US operation 'Desert Storm' in Iraq it is estimated that 11,000,000 were fired from rockets, of which 220,248 were fired in the first 5 min [3].

[2] These figures represent minimum expenditures as much spending in support of military activities is hidden within civilian budgets.

abstractness' whilst advising that to reach the Soviet Union's 'threshold of horror' would require up to ten million dead [6, 7]. Again, a senior engineer has described his early work as a weapons engineer dealing with sonar, radar, guns and missiles as the 'fun hands-on part' of his career [8]. Commercial engineering enterprises usually take great care to assess fully and make known the effect of their activities on persons, communities, the environment and the economy. However, the annual reports of arms companies do not record the number of civilians injured or killed by their products, and requests for such information are declined on the grounds of not commenting, on principle, on individual customers or individual contracts. Nevertheless, such information has been recorded: for example, analysis of Wikileaks documents shows that 201 civilians have been killed and 498 civilians injured in Iraq by weapons with components from Norwegian arms companies [9]. Finally, professional engineering associations can play an important role in leading informed debate about the role of engineering. However, their contribution to discussion of the suffering caused by military engineering is notably absent.

3.3 The Temptations of Military Technology

Certain types of weapons have been considered so horrendous that their use has been proscribed by international law. Important examples of such restrictions include the Biological and Toxin Weapons Convention (1972), the Chemical Weapons Convention (1993) and the recent Convention on Cluster Munitions (2010).[3] These conventions have made valuable contributions to the protection of life. However, they also have limitations. For example, major producers and users of cluster munitions, including Israel, Russia and the United States, have not signed the CCM. Furthermore, there are always temptations to find ways around such legislation or to develop entirely new types of weapons. Two of the many such possibilities will be noted here: the use of drugs as weapons and the use of drones (unmanned aerial vehicles).

Governments, industries and universities are currently undertaking considerable work on military applications of new biological knowledge. Such approaches are often euphemistically described by their proponents as 'drugs as weapons' or 'non-lethal weapons' and typically target neurological activity, with possibilities for ethnic selectivity. There is ambiguity as to whether they are covered by the BTWC and CWC. Engineering skills are needed for the scale-up of the production, purification and encapsulation of the active ingredients of such weapons, and to

[3] Biological and Toxin Weapons Convention (BTWC), *Convention on the prohibition of the development, production and stockpiling of bacteriological (biological) and toxin weapons and on their destruction*; Chemical Weapons Convention (CWC), *Convention on the prohibition of the development, production, stockpiling and use of chemical weapons and on their destruction;* Convention on Cluster Munitions (CCM).

provide the theoretical and practical basis for their deployment, probably as dispersed aerosols.

As the development of such weapons also requires medical skills, the British Medical Association (BMA), which represents doctors in the UK, has published a detailed assessment of the topic [10]. The overall conclusion is that 'the BMA is fundamentally opposed to the use of any pharmaceutical agent as a weapon', with key reasons including the need to uphold existing law unequivocally (BTWC and CWC) and the multiple, and probably insurmountable, difficulties that will prevent the use of pharmaceuticals as weapons without causing innocent deaths and disability. This conclusion is consonant with the BMA's overall guidance on the involvement of doctors in weapons development:

> …the BMA considers that doctors should not knowingly use their skills and knowledge for weapons' development…through their participation doctors are lending weapons a legitimacy and acceptability that they do not warrant. Doctors may consider that they are, in fact, reducing human misery through their involvement, but in reality the proliferation of weapons shows this to be untrue [11].

This authoritative analysis should also give cause for concern to any engineer approached with a proposal for work in this area.

One of the key promoters of ethical action is proximity. Indeed, as noted in Chap. 1, an ethical act has been perceptively described as 'a response to the being who in a face speaks to the subject and tolerates only a personal response' [12]. Correspondingly, it is known that even highly trained soldiers are averse to killing at close range. However, a major current technological priority is the development and use of sophisticated weapons that allow remotely controlled killing at great distances, particularly aerial drones but also land and sea equivalents. These are an attractive option for the military due to their relative cheapness in comparison with manned equipment and because there is essentially no risk to their operators.

Drones are widely used in Afghanistan whilst being controlled from Nevada, USA. Some are used for surveillance, but others are equipped with bombs and missiles. The latter are reported to cause many civilian casualties, though quantitative data are difficult to obtain as they are often used in remote areas with inadequate monitoring of effects. Well-informed and expert analysts have expressed great concern about their use. Thus, a report to the United Nations General Assembly Human Rights Council [13] has described such weapons, which are operated through computer screens, as giving rise to a risk of a 'Playstation' mentality to killing. Again, one of the most senior UK judges has compared drones to internationally forbidden weapons such as land mines and cluster bombs, 'so cruel as to be beyond the pale of human tolerance' [14]. A further concern is that the development of drones has facilitated targeted killings ('state-sanctioned assassinations') outside of war zones. For example, there were more than 110 missile strikes by US drones in Pakistan during 2010, and they have been used in other states outside war zones, such as Yemen. Such use is authoritatively regarded as being in most circumstances illegal under international law. Human operators currently control most drones, but increasing automation is in progress with the aim of computer-controlled selection and destruction of targets. This creates a further distance between the initiator of the action and the victim, and makes less clear the allocation of ethical and legal responsibility for the action.[4]

Drugs as weapons and drones are just two of the very many types of weapons which are currently under engineering development, with potential for hugely deleterious effects on human wellbeing. Further analysis of the contribution of engineering to war and peace can begin by consideration of 'just war' theory.

3.4 'Just War' Theory: A Preliminary Perspective

Recognition that war is one of the most vicious of human activities has led to the formulation of analyses that aim to limit its occurrence and extent, the best known of which is the theory of 'just war'. The many formulations of this theory have subtle differences, but a representative account notes five requirements dealing with the decision to *commence* war (*jus ad bellum*) [15]: (i) there must be a just cause (such as to repel an aggressor); (ii) there must be a just intent (such as to restore peace and justice); (iii) war must be a last resort, every possibility of peaceful settlement having been exhausted; (iv) the declaration of war must be by a legitimate authority; (v) there must be a good prospect of success. There are two further requirements for the *conduct* of war (*jus in bello*): (vi) the innocent (civilian non-combatants) must not be directly attacked (acts should be discriminate); (vii) the means used must be in proportion to the end in view. It is usually made clear that all of these conditions must be met for war to be considered just. Recent accounts also suggest that it is important to consider the likelihood of justice after the war (*jus post bellum*).

Just war theory has been subject to strong criticism. For example, the theory may be viewed as institutionalising conflict assumptions, as it assumes a culture of conflict rather than seeking to promote a culture of peace. The very concept of a 'just' war may be doubted, for armed conflict inevitably results in the death and injury of the innocent. The requirements represent a rather idealised state very different from the irrational political disputes that precede the start of wars and the chaotic conduct of wars. It has also been suggested that the very existence of a set of requirements of this sort makes war more likely, for they can be used speciously to justify war. For example, the doctrine may be used to provide justification for pre-emptive war or even preventive war, where any danger is distant, perhaps no

[4] Proponents of such technology may refer to 'autonomous' systems able to make 'decisions'. Such terminology seems intended to imply mind-like properties, possibly to distract from the responsibility of manufacturers and operators. However, such 'autonomous' drones remain machines.

more than a speculation. Nevertheless, these requirements may provide a useful framework for analysis and discussion. As will be described, the requirements of last resort, discrimination and proportionality are those which are most relevant to engineering.

A substantive recent consideration of the morality of war [16] which is strongly supportive of just war theory notes three features of contemporary war that are pertinent to the present analysis:

1. For Western nations, wars are now undertaken more from choice than from the pressing necessity of territorial defence. For example, there are no current strategic threats to the UK. This increases the need for careful justification of military engagement.
2. War has a protean nature: it readily takes on various shapes or forms. The just war doctrine is primarily directed at war between nation states. However, war now often involves non-state entities such as terrorist and insurgent groups.

It should also be noted that many commercial organisations have a strong financial interest in promoting conflict, including those 'private military companies' (mercenary organisations) that engage directly in hostilities, and manufacturers of weapons and supporting systems.

3. Whereas just war theory has been regarded historically as being directed at only the very highest levels of political and military leadership, responsibility is increasingly being devolved to lower levels: politicians in general, civil servants, officers and 'ordinary service people'.

Furthermore, the responsibility of all is additionally confirmed by the establishment in 2002 of the International Criminal Court (ICC) as a permanent tribunal to prosecute *individuals*, 'without any distinction based on official capacity', for four categories of violent military action (genocide, crimes against humanity, war crimes and crimes of aggression) [17]. All three of these features underlie the following discussion.

3.5 *Jus In Bello*: An Engineering Perspective

Even though responsibility for 'just war' is increasingly seen as applying to individuals at all levels, analysis of just war theory continues to be mostly conducted in very general terms, though reference may be made to military personnel, bureaucrats and politicians. The analysis of nuclear deterrence by Finnis, Boyle and Grisez is somewhat more specific, considering individually the roles of members of Congress or Parliament, submarine commanders, the rather curiously described 'key-turners' and citizens at large [18]. However, there appears to have been no consideration of the specific role of engineers. This is a strange omission, for engineering is the profession that is most essential to contemporary warfare. Engineers are essential for the invention, design, manufacture and use of the sophisticated weapons with which wars are fought. In contrast, the specific skills of bureaucrats, politicians and lawyers are not essential for war. Even military personnel, as traditionally understood, are not essential for newer types or war: drones equipped with bombs and missiles are used around the world whilst being controlled from Nevada, USA through very sophisticated engineering.

It is, therefore, important to examine the role of engineers in just war. It can be beneficial to do so whilst drawing on some key engineering principles. First, it is most important to seek reliable empirical evidence. Second, the engineering virtues of accuracy, rigour, honesty and integrity suggest that the evidence sought should be as far as possible quantitative and comprehensive. Quantitative evidence is much needed, for philosophical discussion of just war has generally been very qualitative in nature even though several of the requirements suggest that some quantitative assessment is necessary. Comprehensive or systems analysis is also vital, for war is a complex phenomenon that needs to be viewed in all its aspects if an overall evaluation is to be made. Third, we need to recall that a theory is only valid if it is borne out in practice.

The contribution of engineering to war is considered by politicians and the military as being concerned with the conduct of war. In this context, the two requirements of just war theory needing consideration are discrimination and proportionality. Politicians and the military frequently claim that recent wars have been just. So from an engineering perspective a question of the following type is appropriate: Is there evidence that recent wars have been conducted in ways that are discriminate and proportionate? An indication of discrimination might be that the proportion of civilian casualties in a conflict is low. An indication of proportionality might be that the overall number of casualties is low. There are many problems in seeking even such simple evidence. For example, the category ‘civilian’ (or some other related category such as ‘non-combatant’) is difficult to define with precision. Furthermore, the term ‘casualty’ needs further definition, for it may include those killed, wounded, or otherwise adversely affected by, for example, psychological trauma, physical displacement or hunger. Even if the term ‘casualty’ is limited to those who die, it may relate to those killed directly by munitions or those who die from other effects of the conflict, such as illness untreated due to the collapse of medical services. Different methods of collecting data will also give different results due to the chaos of war, and casualties in remote places may not be recorded in any way. Additionally, authorities may provide deliberately misleading information. For example, following 7 months of very heavy aerial bombardment of Libya, the Secretary General of NATO, Anders Fogh Rasmussen, stated, ‘We have carried out this operation very carefully, without confirmed civilian casualties’ [19], a statement which is literally incredible unless the words ‘confirmed’, ‘civilian’ or ‘casualties’ are being used in very special senses.

For these reasons, it may be difficult to acquire reliable data for a given conflict and even more difficult to compare and collate data from different conflicts so as to obtain an overall assessment. However, a critical appraisal of data for some major recent wars has been made [20]. For the war in Bosnia-Herzegovina (1991–1995) two different methods estimated that the number of individuals who died or disappeared was 97,207 or 104,732, with 39–40 % being civilians. For part of the war in Iraq (March 2003–June 2006), three studies estimated violent deaths as 58,700, 151,000 and more than 600,000 with a ratio of civilian to military deaths of 3:1, 5:1 and 10:1, respectively. Other conflicts with very high civilian to military death ratios (possibly close to 9:1) are Cambodia (1975–1979), Rwanda (1994), Democratic Republic of Congo (DRC, since 1996), Northern Uganda (since 1986) and Darfur (since 2003). These latter conflicts are in countries that were impoverished and had poor infrastructures even before the onset of violence, factors that can make civilians especially vulnerable. The total numbers of people dying in these conflicts are also very high. For example, 5,400,000 people may have died in the DRC between 1998 and 2007, 90 % as a result of war-related disease, malnutrition and other causes rather than violence (the DRC population is currently about 71 million). The conclusion of this critical assessment was that '*[the] civilian is indeed under extreme threat in war today*'. Civilians do not seem to have the type of protection that the just war principle of discrimination would suggest. Proportionality is more difficult to assess, for it may in principle include a multiplicity of factors. However, the total numbers dying must cast doubt on the proportionality of these wars. It must also be remembered that the numbers of persons physically injured, psychologically traumatised, physically displaced or otherwise severely disadvantaged are very much higher. Consequently, an engineer's assessment would be: *if any of these wars were just, then just war theory has not protected civilians; if all of these wars were unjust, then just war theory has not protected civilians*. Each of these possible assessments poses serious questions about the validity of just war theory.

It may be claimed that these deaths of civilians were not intended, merely foreseen. That is, in military terms they were collateral damage, a status for which philosophical grounding might be sought from the principle of double effect. A recent careful analysis has cast serious doubt on whether this principle can provide a compelling justification for collateral damage [21]. The principle is, of course, the basis of the elucidation of hypothetical quandaries for which common intuition suggests that it might in certain circumstances be 'reasonable' to take an innocent life. However, an evidence-based perspective shows that war inevitably results in the deaths and traumatisation of large numbers of civilians, indeed frequently overwhelmingly civilians rather than combatants. To justify war on the basis of a nuanced distinction between merely foreseen harm rather than intended harm demonstrates a crass neglect of the value of individual persons. Furthermore, such agent-oriented nuances look very different from the viewpoint of the victims.

Manufacturers of weapons frequently make an argument that their most 'sophisticated' weaponry is designed specifically to minimise civilian casualties. The indiscriminate and disproportionate injury and death caused by many modern weapons suggests that such a claim cannot be entirely true. Empirical evidence is again needed, and a detailed and careful study of casualties in Iraq in the period 2003–2008 has shown that 'sophisticated' weaponry used at a distance resulted in a far greater proportion of indiscriminate civilian deaths of women (46 %) and children (39 %) than more primitive techniques used at close range [22]. Experts advise that the patterns found in Iraq are likely to be replicated wherever similar weapons are used. 'Sophisticated' weaponry is very unlikely to produce a technical fix to the problem of the death of the innocent in war. Moreover, in the same way that philosophical discussion of the theory of just war often has an ethereal air unrelated to real violence, so statistics of this sort can mask tragedy. A report from a war correspondent may better convey reality:

> Despite all the videos you see from the Ministry of Defence or the Pentagon, and all the sanitised language describing smart bombs and pinpoint strikes, the scene on the ground has remained remarkably the same for hundreds of years. Craters. Burned houses. Mutilated bodies. Women weeping for children and husbands. Men for their wives, mothers, children [23].

Though statistics often focus on deaths, severe injuries are also the cause of immense suffering. Even experienced medical doctors are shocked when they first encounter war injuries, especially those to children [24]. Use of 'sophisticated' weaponry produces a great number of casualties with extreme injuries [25]. 'Sophisticated' weaponry may also have very long-term detrimental effects on civilians, as exemplified by the high incidence of birth defects in Fallujah (Iraq) since 2003 [26] and the many deaths, injuries and disruptions caused by mines and cluster munitions long after they are deployed.

The search for a technical fix is misguided for a further important reason. As already noted, many of the casualties of war are not the result of major military strikes. They are the result of factors such as the sectarian violence that results from the breakdown of provisions for law and civil order, the collapse of civil infrastructure and the collapse of medical provision. Thus, 'sophisticated' weaponry may increase the initial intensity of conflicts but is very unlikely to promote beneficial outcomes for many civilians.

As war, and especially war carried out with the many contemporary weapons of huge destructive power, has such a disastrous effect on the innocent, it is puzzling that so many engineers have been involved in weapons production. One of the reasons is that engineers are attracted to arms companies by the opportunities offered for working on the development of sophisticated technological artefacts: they are dazzled by the prospects of contributing to technical wizardry. However, analysis of engineering as a practice shows that this involves a misunderstanding of the nature of engineering, for the production of technological artefacts is not the goal of engineering; they are an example of contingent external goods. Engineers need also to consider in a balanced way the other key constituent features of their practice, including ends, internal goods, virtues and the systematic extension of the practice. Advanced engineering will, in particular, seek to balance these constituent features in a way that enhances the flourishing of persons in communities. *A crucially important point is: advanced engineering is not synonymous with advanced technology.*

Another significant reason for the involvement of engineers in weapons production is related to the nature of weapons companies: they are an example of the institutions of the practice of engineering. MacIntyre has noted that institutions are 'characteristically and necessarily concerned with what I have called external goods' [27]. These external goods include money, power, status and for engineering, technological artefacts. Too great a concern with such goods may lead to a distortion of the practice. As noted in Chap. 2, MacIntyre and others have considered whether perverse practices might exist. Maybe it is more appropriate to propose that *perverse institutions* may arise within practices, and if so, evidence suggests that weapons companies fall into such a category. The products of such companies certainly cause many innocent deaths and immense suffering. Weapons companies are the only entities to benefit unequivocally from violent conflict, often by supplying all sides in a conflict, as occurred recently in Libya. Furthermore, corruption in the arms trade is reported to account for 40 % of all corruption in global transactions [28]. Such companies describe the work of their engineers in euphemistic terms and adopt work practices that minimise an individual employee's appreciation of the overall purpose of his or her work, so as to curtail the imagination of the use of the weapons produced. Nevertheless, an engineer employed by a weapons company risks the corruption of the ethical coherence of his or her life, in a way analogous to that in which a torturer's life may become corrupted. Additionally, it is difficult to harmonise the activities of weapons companies with the socially beneficial practices of most communities.

3.6 *Jus Ad Bellum*: An Engineering Perspective

Little attention has been given by politicians and the military to the role of engineering in dealing with a decision to commence war. The five requirements of *jus ad bellum* appear to be less amenable to empirical or otherwise mutually agreed assessment than the requirements of *jus in bello*. One certainly does not have to be very sceptical to consider that the first and second requirements have been the subject of cynical political exploitation. For example, rather than careful consideration of just cause and just intent, the US approach to the start of the 2003 Iraq war has been described by a leading proponent of just war theory as 'another day, another reason' [29]. The fourth requirement, for declaration of war by a legitimate authority, implies an ordered approach to war by nation states, a situation that does not describe the origins of many contemporary conflicts: over the decade 2001–2010 only 2 of 29 major armed conflicts have been classified as interstate [28]. Non-state entities, such as terrorist organisations and militias, are unlikely to proceed in such an ordered manner. Also, as noted previously, states such as the US are making widespread lethal strikes by remotely controlled drones outside of recognised conflict zones, although these are considered illegal under international law. Many civilians have been killed in this way. The development of drones, which can reduce ethical awareness due to the great distance between agent and victim, could be taken to show that engineering facilitates the circumvention of just war approaches to conflict. Engineering might be seen as a way of meeting the fifth requirement, that there must be a good prospect of success, through the provision of weapons of immense destructive power. However, recent conflicts show that even an overwhelming advantage in both the number and 'sophistication' of weapons in no way guarantees military domination.

It is the third requirement that should be of most concern to engineers: that war must be a last resort, every possibility of peaceful settlement having been exhausted. Indeed, as the deaths and traumatisation of innocent civilians are examples of immense injustice, seeking means of peaceful settlement could be seen as an *obligation* of professional capabilities, as described in Chap. 2, if engineers can offer viable alternatives. Here another key feature of engineering again becomes important: that comprehensive or systems analysis is vital. Engineers particularly seek to understand the root causes of problems under investigation, rather than simply proximate determinants, for then a lasting solution may be found. In this context, the perceptive analyses by the Oxford Research Group of current threats to peace and of the most effective responses are particularly relevant. The Group characterises the predominant current military strategies as following a power projection *control paradigm*—an attempt to maintain the existing state of affairs through military means. It proposes that a more effective approach is a *sustainable security paradigm*—to resolve cooperatively the root causes of threats using the most effective civilian means available [30, 31]. The Group identifies four factors as the likely root causes of possible future insecurity and conflict:

1. Climate change—leading to loss of infrastructure, resource scarcity and mass displacement of peoples, causing civil unrest, intercommunal violence and international instability.
2. Competition over resources—including food, water and energy, especially involving unstable parts of the world.
3. Marginalisation of the majority world—increasing socioeconomic divisions and the political, economic and cultural marginalisation of the vast majority of the world's population.
4. Global militarisation—the increased use of military force as a security measure and the further spread of military technologies, including chemical, biological, radiological and nuclear weapons.[5]

[5] Ideologically-inspired terrorism is not included in this list of root causes of major conflicts. Whilst the Group recognises that terrorism represents a threat to communities, it does not regard it as a major strategic threat at present. Furthermore, it is particularly important to note that key experts regard the use of conventional military force to address the threat of terrorism as counter-productive. Thus, the Director General of the UK security service MI5 between 2002 and 2007 has advised that 'the invasions of Iraq and Afghanistan radicalised parts of a generation of Muslims who saw the military actions as an "attack on Islam"…Arguably, we gave Osama bin Ladin his Iraqi jihad' [32]. At the same time, the Chief of the UK Defence Staff regarded military victory against al-Qa'ida and the Taliban as not possible [33].

There is good evidence for these root causes, some of it surprisingly quantitative. For example, in the tropics there is a climate oscillation known as the El Niño/Southern Oscillation (ENSO) with a 3 °C variation in sea temperature occurring approximately every 5 years between El Niño (warm) and La Niña (cool). Studies of data from 1954 to 2004 have shown that the risk of organised political violence ('civil conflict') doubles, from 3 to 6 %, in affected nations during the warm part of the cycle, with less developed countries being particularly badly affected. The oscillation may have had a role in 21 % of conflicts (out of a total of 230) in the period studied [34]. Many factors are involved, but food availability and cost may be important as crop yields are greatly reduced in El Niño years.

Engineers have the knowledge and skills to play a major role in resolving these root causes of conflict. For instance:

1. As effects such as El Niño can be predicted, action can be taken to reduce their impact.
2. Development of renewable energy sources and transition to low carbon energy economies can reduce global climate change.
3. Improved efficiency, better recycling and the introduction of innovative processes and materials can reduce resource competition.
4. Generation of wealth through the introduction of appropriate engineering processes in impoverished societies can diminish marginalisation.
5. Reducing or halting weapons development and production, and thereby reducing trade in arms, can limit militarisation.

As an example, consider the conflict in Darfur that has caused extensive loss of life and much suffering. The origins of this conflict are complex, but access to water was an important issue. Darfur was severely affected by a long-term drought in North Africa. The conflict was triggered by the resulting clashes over access to water and pasture between small groups of black African farmers and Arab pastoralist communities. The conflict escalated as the groups grew bigger. Eventually a government-backed militia, the Janjaweed, became involved. This militia would terrorise local villagers, displacing them from their homes and hence taking control of water sources. The traditional source of water for many villages in Darfur was surface lakes that filled during the rainy season. The drought interrupted this supply. An engineering solution is to drill boreholes accessing deeper water and equip them with submersible pumps. A number of NGOs are now involved in such work. The extent of this conflict is a stark reminder of how a timely application of relatively simple engineering for the provision of water might have prevented much suffering. However, water engineering does now have a role in resolving the conflict, and may have a very significant role in relieving tensions related to water that are apparent between a number of states, including: Israel, Jordan and Palestine; Syria and Turkey; China and India; Egypt, Sudan and Ethiopia; Angola and Namibia [35].

Hence, from an engineering viewpoint, the requirement that war must be a last resort is extremely challenging. There are multitudes of ways in which engineers can seek to provide the conditions for a peaceful settlement to a dispute. These options are particularly important for those Western nations that now undertake wars more from choice than from the pressing necessity of territorial defence. In such circumstances there may be good time for thorough consideration and implementation of non-violent alternatives. The unpredictable forms in which war arises also provide good reasons for addressing the identifiable underlying causes. These options are also very relevant to 'humanitarian interventions' around the world. In many of these, appropriate civilian engineering interventions may be more effective than military engagement, which always entails great uncertainty in outcome and very often an incompatibility of means and ends. However, it may be suggested that the acuteness of the humanitarian need demands rapid military intervention. This may sometimes be so, but such situations point to an aspect of military conflict that has been mostly ignored in just war theory: considerations needing attention in preparation for war, which might be termed *jus ante bellum*.

3.7 *Jus Ante Bellum*: An Engineering Proposal

The idea of *jus ante bellum* has received very little attention, and then always from the viewpoint of military personnel. One appraisal has focused on the ethical education of personnel at a naval academy, *jus in disciplina bellica* [36]. Another tentative proposal has suggested that it might be used as a term for the preparations necessary to produce a competent and effective military force capable of delivering just war [37]. However, the present proposal is much broader in scope and is concerned with the resources used in preparation for war, or to avert war. This consideration may also be viewed as an opportunity of professional capabilities, as described in Chap. 2, arising from the immense suffering which remains unalleviated as resources are diverted to the production of weapons.

It has been noted that about one third of all engineers are employed in military activities and that the total financial resources used globally in preparation for war are enormous. A key issue in the proposed engineering conception of *jus ante bellum* is whether such expertise and resources could be used in better ways both to promote human flourishing and to avert conflict. An example will be given for the case of access to water. It has been noted that access to water was a significant factor in the war in Darfur and is the source of tension in many other places. A range of engineered processes, both simple and advanced, is available for the production of safe drinking water and for sanitation. Developed countries can afford the costs of installation of advanced and expensive processes. However, even simple processes are often not available in developing countries. As a result, and despite some recent progress, 783 million people do not have safe drinking water and 2.7 billion people have no provision for basic sanitation [38]. As a result, 3,000 children die *daily* from diarrhoeal diseases, and the social and economic consequences of adult ill health are also enormous. It is in such developing countries that water stress is presently most likely to lead to violent conflict. If there is genuine commitment to seek appropriate and cost-effective means of averting such conflicts, it is pertinent to compare military and water costs.

The costs and benefits of water and sanitation improvements at a global level have been quantitatively evaluated [39]. Five levels of intervention were considered, two of the most significant of which are:

(a) Halving the proportion of people who do not have access to improved (simple) water resources and improved (simple) sanitation facilities by 2015, a Millennium Development Goal target.
(b) Access for all to a regulated piped water supply and sewage connection into their houses.

All interventions were compared to the situation in 2000 and costed to include full investment and annual running costs. The total annual costs of the two outlined here were estimated to be (a) US$11.3 billion, (b) US$136.5 billion. It is easy to lose an awareness of individuals in global calculations of this type, so it is helpful to consider the annual cost per person receiving interventions: (a) US$5.4, (b) US$20.6. These are very modest sums in the context of the benefits to the individuals. There are, of course, many uncertainties in such calculations and detailed country case studies are required. However, it should be noted that the annual cost of the least expensive intervention is a tiny 0.7 % of world annual military expenditure. Even the annual cost of the most expensive intervention is only 8 % of world annual military expenditure. That many deaths and much suffering could be relieved by the diversion of relatively small amounts of the budget for the preparation for war to the supply of essential resources to the poorest of the world's population is a major injustice that should be of widespread concern.[6]

However, continuing to focus on this particular resource, *jus ante bellum* could also consider access to water supplies as an opportunity rather than a problem. In particular, water provision could be seen as an instrument for socio-economic development, security and peace, an approach that has been termed *Blue Peace* [40]. This approach has been proposed, at high engineering and political levels, particularly for those areas of the Middle East where tensions about water supply exist: first, the northern countries (Turkey, Syria, Iraq, Lebanon and Jordan), and secondly the southern countries (Israel and Palestinian Territories). Collaboration in establishing common standards for measuring water flow and quality, setting and implementing goals for sustainable water resource management, and promotion of regional strategies to combat drought arising from climate change could provide a shared investment in the most essential of resources and hence provide an important motivation for peaceful coexistence.

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[6] The costs of universal provision of electricity are compared to military expenditure in Chap. 5.

Greater awareness of the need to consider *jus ante bellum* should lead to greatly reduced expenditure on the development and manufacture of ‘sophisticated’ weapons. This would lead to an additional important benefit, for weapons manufacturing is research intensive, employing a high proportion of the most able engineers [41]. Release of these highly qualified but adaptable personnel to other forms of employment could give a great boost to the development of imaginative means of promoting *jus ante bellum* engineering approaches to the other root causes of conflict.

3.8 Just Engineering and Active Peacemaking

The phrase *jus ante bellum* still suggests a culture of conflict and eventual preparation for violence. Indeed, a number of approaches to peace are also closely linked to responses to war. Peacekeeping implies a response to existing violence or threat of imminent violence. It is one of the few forms of peace to which states expressly commit resources, though this commitment is small compared to commitments in preparation for war. For example, the UN peacekeeping budget for 1 July 2011–30 June 2012 was US$7.84 billion [42]. Activities such as peacemaking and peacebuilding are also usually understood to refer to post-conflict activities, though they may be understood, at least in part, to refer to activities not connected with existing conflicts if more precisely designated by terms such as *just* peacemaking [43] or *strategic* peacebuilding [44].

Peace in itself is mostly neglected, and an important reason for this neglect is that although war and preparation for war are seen as activities, peace is regarded as a condition [45]. This is partly a reflection of the nature of our culture and its focus on singular events that occur on the timescale of a news cycle; war takes place more rapidly and is more dramatic than peace. However, it reflects more profoundly a failure of analysis and perception, particularly a forgetfulness of the value of each human life and of the inadequacy of approaches such as that of classical just war theory to protect such life. *Jus ante bellum* shows that there are other approaches, and a full expression of these approaches is a commitment to *active peacemaking* as the preparation that can best ensure the flourishing of all persons. Various types of active peacemaking have been proposed previously, such as Gandhian *satyagraha*, Quaker consensus and various types of negotiation techniques. However, it is proposed here that engineering has a particularly important role to play, and this type of engineering may be termed *just engineering*.

Engineering provides a range of knowledge and practical skills that may be used to address the key roots of conflict. In particular, just engineering can uniquely contribute to active peacemaking by providing solutions to some of the crucial needs identified in strategic analyses:

1. Just engineering can provide *practical solutions* to local needs whether they arise from competition for resources, economic marginalisation, climate change or other factors. Such concrete (sometimes literally so) solutions can foster just

and sustainable development. Sustainable economic development is a key promoter of peace [46].

2. Just engineering activities can directly *commit communities* in potential conflict to common projects of benefit to all. This shared commitment may be enhanced if engineering that employs the skills of local people is prioritised. In many places in the world this may involve the application of labour intensive engineering to meet basic needs rather than the use of the latest technological devices. Insufficient attention to the everyday needs of the population has been a weakness of previous peacemaking activities that have focused too greatly on force and security [47].
3. Just engineering can provide *non-violent means* of meeting humanitarian needs and of preventing the build-up of tensions, both of which are presently associated with the temptations of preventive or pre-emptive military action. Such non-violent interventions could be initiated by states, but they could also be initiated by commercial organisations or charitable bodies either internationally or locally. These latter possibilities are free from the restrictions which international law currently places on state interventions.

Just engineering makes particular use of an important characteristic of engineering identified in Chap. 2: it is an *enabling* activity that enhances the agency of others by providing them with the means for advancing their goals and values. This is particularly useful in the case of peace, for a major challenge is to change the perception of peace from that of a condition that somehow has arisen to an activity that requires continual commitment and imaginative input.

Furthermore, just engineering has a number of key features that are absent from just war approaches:

respect for the full and equal human status of every person;
congruence of non-violent means and ends in the promotion of peace;
recognition that peace involves much more than the absence of conflict.

Just engineering, the long-term commitment to use practical knowledge and skills in active peacemaking, is a task that engineers should promote and in which they can take a leading role.

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Chapter 4
Engineering for Health

4.1 Introduction

Engineering can make many contributions to the conditions that promote good health, including the provision of clean water and sanitation, buildings that provide shelter and improvements to the effective growth and storage of food. Engineering can also make important contributions to the care that is needed when health fails. Indeed, such contributions are increasingly leading to greater entanglement of the activities of engineers and healthcare professionals. This chapter will first consider some aspects of recent technological innovation in healthcare and the ethical challenges and opportunities that arise in such healthcare engineering.

Engineering activities can in some circumstances have deleterious effects on health, mostly as unintended consequences of otherwise desirable activities. Hence, another form of entanglement of the activities of engineers and healthcare professionals is the increased awareness in the medical profession of the effects of engineering policy and activities on health. Thus, this chapter will secondly consider one example of such awareness, the effects of transport infrastructure and policy on health.

4.2 Trends of Engineering Innovation in Healthcare

In 2007, the *British Medical Journal* published a supplement entitled *Medical Milestones*: *Celebrating Key Advances Since 1840* [1]. The benefits of fifteen advances were highlighted: anaesthesia, antibiotics, chloropromazine, DNA structure, evidence-based medicine, germ theory, immunology, medical imaging, oral contraceptive pill, oral rehydration therapy, sanitation, risks of smoking, tissue culture and vaccines. In a subsequent poll, readers were invited to vote for the advance that they rated most highly. The most supported advance was the development of sanitation (clean water supply and sewage disposal). This assessment by medical professionals is remarkable, for the development of sanitation is not strictly speaking a *medical* advance, it is an *engineering* advance.

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Engineering makes profound contributions to our health in many ways. At the most basic level, such contributions derive from the provision of the infrastructure on which our societies depend. In addition to sanitation, these include suitable buildings, both domestic and specialised (such as hospitals), dependable sources of energy, and equipment and procedures for the safe harvesting and storage of food. At a more specific level, engineering contributes to the enhancement of our health through activities such as the large-scale manufacture of pharmaceuticals and the design of the many different types of diagnostic and support equipment on which modern hospital healthcare depends.

At these basic and more specific levels, engineers are working to enhance the wellbeing and health of all. In carrying out these activities they may only rarely have direct contact with the beneficiaries of their work. Even in the case of hospital diagnostic and support equipment it is usually healthcare professionals, rather than engineers, who use the equipment in the treatment of individual patients. Thus, much ethical assessment of such engineering activities has been made at the level of benefit to whole communities, though always seeking to ensure that no individual is unfairly disadvantaged. This is in contrast to the emphasis in medical ethics on the individual patient affected by the doctor's actions [2].[1]

However, some important current trends in healthcare are leading to an entanglement of the activities, and hence ethical responsibilities, of healthcare professionals and engineering professionals. One of the most important of these trends is the increasing reliance on ever more sophisticated technology throughout healthcare. Another is the move to reduce the number of patient visits to clinics, and to reduce the number and duration of patient stays in hospital, by increasing the availability of monitoring and treatment in the home. These and other trends further increase the prominence of engineering activities in healthcare and lead to a need for reassessment of engineering ethics so as to give appropriate expression of, and attention to, the specific needs of individual patients as well as the generic needs of communities.

4.3 Engineering Innovation in Healthcare: Technological Aspects

There is currently a very wide range of engineering innovation in healthcare. Such diversity makes it difficult to identify a fully agreed terminology to distinguish these differing developments. To facilitate a subsequent ethical analysis, the following sub-sections will consider some of the main types of innovation in three broad categories: assistive technologies, telehealthcare and quasi-autonomous systems. This represents a sequence of increasing technological sophistication and also, as will be discussed later, a sequence of increasing ethical complexity.

[1] There are, of course, also aspects of medicine that focus on the health of populations.

4.3.1 Assistive Technologies

Simple assistive technologies have been familiar for many years. For example, the great innovator Benjamin Franklin is credited with inventing, in the eighteenth century, an extension device allowing people with arthritis to handle small objects. Many homes are now equipped with physical or mechanical devices such as ramps, grab rails, level access showers and stair lifts. Some electronic devices may also be considered as assistive technologies. These include simple alarm systems, such as a pendant that may be used to alert a contact centre if a person needs assistance due to an accident or sudden ill health. Another type includes devices such as portable 'personal digital assistants' that can provide reminders to people with memory loss, perhaps as an aid to recovery following brain injury [3]. The use of such systems is under the control of the person benefiting. Their great advantage is that they enable people to live more independently in their own homes.

Simple assistive technologies are also used extensively in healthcare institutions. For example, mechanical lifting devices may allow patients to be moved more safely and with less physical strain on nursing staff. In physical rehabilitation, mechanical devices can also enhance physiotherapy and physical training with less strain on healthcare staff. Simple devices are always under the control of the healthcare staff or patient, but automation offers further possibilities. For example, a more advanced device may use a computer, with monitoring and feedback, to offer encouragement to the patient to carry out the repetitive exercises that physical rehabilitation requires. Thus, the device may be designed to fulfil some of the motivational role previously carried out by the healthcare staff. Furthermore, electronic assistive devices may also be used in the diagnosis and treatment of individuals with cognitive disabilities or developmental and social disorders [4].

Another form of assistive technology is computer assisted surgery, which is widely used to carry out minimally invasive procedures. Typical uses are in prostate surgery, cardiac valve repair and gynaecological procedures. The surgeon controls manipulations through a console that allows smooth and very fine actions. Though this technology has clear advantages, the overall benefits are the subject of discussion. The high capital and operating costs are a drawback. Furthermore, procedures are often misleadingly described as 'robotic surgery' even though the surgeon is always in control. 'Remote access mechanically assisted surgery' has been proposed as a more honest description [5].

4.3.2 Telehealthcare

Telehealthcare is the provision of personalised healthcare over a distance [6]. The patient may be provided with equipment to monitor their condition. The data obtained, such as electrocardiography, oxygen saturation levels or glucose levels, is sent electronically to a healthcare professional. Interaction between patient and healthcare professional may also take place using voice or video links. The healthcare professional then provides assessment and advice to the patient.

Telehealthcare may be of particular benefit to patients with long-term conditions, such as heart disease, asthma or diabetes, and to patients with limited mobility or those who live in remote areas. The aims of telehealthcare include 'to widen access, improve clinical endpoints, aid the early detection of disease exacerbations, reduce the risk of hospital admissions, reduce mortality or reduce the degree of dependency in old age' [7]. Telehealthcare clearly depends greatly on the reliability of sophisticated equipment. It also depends on such equipment being easily and correctly used by patients without prior technical or medical expertise. If functioning successfully, telehealthcare may give patients a more active role in the control and treatment of their condition. Such care at a distance may also change the nature of the relationship between the patient and the healthcare professionals, and may change the role of specific healthcare professionals: for example, nurses may acquire greater responsibility and specialist doctors may take roles usually fulfilled by general practitioners.

4.3.3 Quasi-Autonomous Systems

The technology described so far has been either under the direct control of the person benefiting (patient), under the direct control of a healthcare professional or involves collaborative action by the patient and professional. However, use of increasingly sophisticated technology can result in highly automated systems or even systems which appear autonomous.

Simple systems such as pendant alarms are under the control of the user. However, it is possible to monitor a person's activities in a home by a great variety of means. For example, sensors can detect the use of doors, chairs or beds and can even distinguish different types of motion around a room. Video and sound monitoring may supplement such sensors. All of this data can be stored or sent directly for assessment at another location. If a person leaves their home, inexpensive global positioning systems (GPS) can monitor their movements and allow their tracking on a personal computer. Such lifestyle and location monitoring may be used in the care of vulnerable persons, such as those with dementia.

The engineered devices described so far in this subsection have been concerned with alleviating the effects of physical or cognitive impairment. However, the so-called 'socially assistive robots' are proposed as a means of meeting needs for companionship and emotional support [8, 9]. They have been developed, particularly in Japan, for use in the care of elderly persons who are socially isolated. They often have the form of toy animals and have been suggested as sources of pet-like companionship without the requirement for pet-like physical care. Sophisticated robotics allows them to appear to respond to verbal commands and physical interaction in ways that suggest autonomy.

At the forefront of engineering innovation in healthcare are ways of interfacing devices such as prosthetic limbs to the peripheral nervous systems and brain [10]. These can, for example, aim to allow movement of a prosthetic limb with subconscious control of a type similar to that of natural limbs. Such developments raise issues regarding the nature and status of the delegated action, which is partly controlled by a microprocessor. Provision of non-invasive brain-computer interfaces to aid patients with degenerative conditions such as amyotrophic lateral syndrome ('locked-in syndrome') may require very detailed knowledge of how the brain processes information and how this is affected by the condition.

4.4 Engineering Innovation in Healthcare: An Ethical Assessment

This section seeks to contribute to an ethical assessment of some of the recent engineering innovations in healthcare by making use of the approaches to engineering ethics that have been outlined in Chap. 2. Two aspects of this analysis are especially relevant. First, that there is a danger of focusing too greatly on the external goods of technological artefacts. Such a focus may lead an engineer to pose questions in the form 'what kind of technology can best meet the healthcare needs of the person?'. That is, what can be *done for* the person? However, this places the person benefiting in a passive role. A more aspirational approach may further ask, 'what can the person do?', which is to consider the person's agency as well as his or her wellbeing. Second, specific attention needs to be given to ensure, as far as is practicable, that engineering activities do not unfairly disadvantage any individual in a community. In the context of innovative engineering for healthcare, it is appropriate that this is expressed more positively: that engineering is applied, as far as is practicable, to meet the specific healthcare needs required to promote each person's wellbeing. The analysis will emphasise aspects relating to older persons, who are often envisaged to be the primary beneficiaries of such engineering, though many of the comments made may apply to persons of any age who may benefit from such medical treatment or care. Some important general considerations will be noted followed by attention to features more specific to each of the categories of assistive technologies, telehealthcare and quasi-autonomous systems.

4.4.1 General Considerations

In Chap. 2, engineering has been described as a practice with certain features, and engineering for healthcare retains these features. For example, engineering for healthcare provides great opportunities for the expression of the internal goods associated with technical excellence and may result in substantial external goods, especially technological artefacts. The virtues that were noted to be particularly relevant to the practice of engineering remain relevant and some specific applications of these virtues will be noted later. Innovation in healthcare provides great opportunities for systematic extension of the practice of engineering. However, engineering innovation in healthcare may benefit from further consideration of the expression of the goal of engineering.

As has been noted, it is difficult to provide a succinct expression of the goal of an activity as complex as engineering in general, but it has been suggested that this may be described as *the promotion of the flourishing of persons in communities through contribution to material wellbeing*. Such expression recognises that engineering typically benefits whole populations, with an implication that many of the beneficiaries already benefit from capabilities such as good health, freedom of movement and freedom of interaction with others. However, the beneficiaries of engineering for healthcare may have, at least at that time in their lives, an increased vulnerability perhaps coupled with restrictions on their movement and interactions. Furthermore, the requirements of each person may be very specific. Thus, engineers involved in engineering for healthcare may need to seek closer involvement with each person benefiting from their work, so as better to understand their requirements and expectations.

Such closer interaction with beneficiaries will be welcomed by many engineers, for one of the difficulties of engineering, in general as a profession, is that engineers often lack the close proximity to persons affected by their work that can engender compassion and generosity. However, conversely, many of the healthcare technologies being developed by engineers may result in increased distance, and less frequent personal contact, between healthcare professionals and beneficiaries. The potential deleterious effects of such distancing should not be underestimated, for proximity is one of the key promoters of ethical action. Other professions have shown the very serious ethical consequences of distance. For example, as noted in Chap. 3, use by the military of remote control weapons such as drones can give rise to a 'Playstation' attitude to killing. Furthermore, as noted in Chap. 1, the extensive use of computerised trading may well have contributed to the decreased sense of ethical obligation in banking. Thus, a new challenge arises for the engineer: to design technology and technological procedures that can, as far as possible, stimulate appropriate personal interaction between the healthcare professional and the beneficiary.

A capabilities approach may stimulate thinking in a way that can help meet this challenge. It was previously noted that a capabilities approach gave a richer description of the beneficiary by considering both wellbeing and agency. Additionally, a capabilities approach leads to a framing of the needs of a potential beneficiary in terms of human functionings rather than goods. Thinking in terms of such functionings can direct an engineer's attention to the beneficiary as a person requiring human care, instead of focusing solely on the external goods of technological artefacts.

A further issue of general ethical significance about which engineers need to show responsible leadership is terminological honesty. For example, much of the literature, and especially the non-specialist literature, dealing with engineering innovation in healthcare uses the term *robot*. Robotics is, indeed, an important branch of engineering, but the public vision of a robot owes much more to science fiction films than to engineering and hence gives a false impression of the capacity of automated devices. Most particularly, it is very much easier to dress up an actor to 'act like a robot', than to manufacture a robot that can act like a person. Thus, as noted previously, 'robotic surgery' is more honestly described by a term such as 'remote access mechanically assisted surgery', for robots do not perform surgery, surgeons do. Responsibility could be shown by the use of similarly precise terminology for other technologies. Another related, common and misleading terminological inexactitude is *autonomous system*, intended to imply an ability to make decisions, that is, to have mind-like properties. However, all existing, and practically envisaged, engineered artefacts are not more than highly automated, rather than autonomous. That is, they use logic to follow a set of rules and instructions and are not capable of human levels of situational understanding. They may, however, appear to an uncritical observer to do more than this, and are hence described in this book as quasi-autonomous.[2] A third and more general danger is *terminological slippage*. Thus, even cautious and insightful academic authors can use, without scare quotes, terms such as 'robot personality' and 'the level of extroversion-introversion of the robot' [11], or describe a robot as having 'a face that is able to express emotions' [12]. In the context of the original articles, where it is elsewhere made clear that these are only apparent features, such slippage is possibly justified to avoid pedantry, but problems arise if such statements are cited without further explanation elsewhere.

4.4.2 Specific Considerations

Each of the three broad categories of technological innovation in healthcare under consideration also gives rise to the need for more specific ethical assessment.

Assistive technologies Simple assistive technologies used in the home or in healthcare institutions are generally under the direct control of the beneficiary/patient or healthcare professional. As with all engineering, the virtues of accuracy and rigour are important. A high prioritisation of safety and reliability is characteristic of all engineering work, and will be especially important for the design of such technologies for the home, where they will be used by beneficiaries without technical expertise or extensive training. For both mechanical and electronic devices, it is important to develop equipment at a level of sophistication that is suitable for beneficiaries with differing types of impairment, so as to avoid the

[2] As the operation of such systems depends on a multitude of externally imposed rules, alternative appropriate descriptions could be 'polynomous' or 'heteronomous', or perhaps just 'complex automated systems'.

exclusion of certain users through design features that might in other circumstances be regarded as benefits, such as miniaturisation of controls.

A different type of distancing may occur during the use of computer assisted surgery: the surgeon operating whilst viewing a screen at a console may have more limited interaction with the other staff of the operating team than during a conventional procedure. Monitoring of information on screens may also change the way that healthcare staff interact with each other or with patients during other assessments and procedures, even if all concerned are in close physical proximity. Such instances provide engineers with the challenge to produce equipment designs that promote, as far as possible, undistracted face-to-face, and hence person-to-person, interaction.

Telehealthcare Issues of safety and reliability remain very important in telehealthcare. The demands of developing equipment at an appropriate level of sophistication may be especially great, for telehealthcare often requires quantitative measurement by the patient in a home environment. One of the potential benefits of telehealthcare is that it can increase the agency of patients, as they become more active in the treatment of their condition. However, such benefit may be diminished if they feel unable to cope adequately with their monitoring equipment.

The dangers of social distancing and isolation, and hence the challenge to find engineering solutions that stimulate appropriate personal interaction between the healthcare professional and the patient, are especially apparent in telehealthcare. As noted previously, telehealthcare may also change the role of different types of healthcare professionals. Hence, technology needs to be developed in close collaboration with healthcare staff so as to ensure that the involvement of all kinds of staff is balanced. This may particularly involve the design of systems that allow appropriate ownership of and access to data whilst safeguarding patient confidentiality.

Quasi-autonomous systems It is with these systems that all of the ethical issues so far considered converge. Resolving the issues that arise can be complex, especially as such systems may be proposed for the care of the most vulnerable persons.

Home monitoring may allow vulnerable persons to continue to live in the home environment with which they are familiar, hence helping to maintain continuity with at least part of their ecological self that is important in their life story. However, obtaining their consent for such monitoring may be difficult, due to a general diminishment of mental capacity or due to a more specific difficulty in understanding the nature of electronic devices. The operation of such monitoring also gives rise to issues concerned with how, and by whom, the data arising is to be monitored, and how it is to be stored. Should there be, for example, 'black box' recording of data so that lessons may be learnt when outcomes are unsatisfactory? Furthermore, conflicts may arise between a proposed, somewhat infirm beneficiary, who may wish to be unmonitored, and concerned relatives, who may prefer monitoring. It has even been proposed that we should be asked when reaching a certain age, say 65, and while still of sound mind, how we would like to be treated should we find ourselves in such a situation [13].

The development of 'socially assistive robots' is probably the most ethically contentious of all present engineering innovations in healthcare, and raises profound issues regarding respect for personhood. Though there is some qualitative experience and limited quantitative evidence that such technology may have positive effects, research design has been inadequate to establish this [14]. The most detailed philosophical analysis argues that the use of such technology involves an ethically unacceptable deception, for the supposed benefits depend on vulnerable people thinking that such robots are something that they are not. That is, thinking that they are at least to some extent 'persons', whereas they are rather entities that are entirely at our disposal, things [15]. As things, they can have no shared background of experiences, no life story, no hinterland of interests and no concern for others. 'Socially assistive robots' may also be viewed as simple versions of 'experience machines' [16], devices which give the illusion of an experience without that experience actually occurring, a further deception. They are certainly much further from 'personhood' than even pets, which may have enough autonomy to at least offer something like companionship, though as one doctor has observed, 'the encouragement one can obtain from a cat is rather limited'.[3] Of especial concern is the use of 'socially assistive robots' as substitutes for genuine person-to-person interaction, resulting in a delusional existence and the neglect of other real persons. A cautionary example of the dangers of simulated interactions is given by the case of Korean parents who allowed their real infant to starve to death due to their obsession with raising a 'virtual child' in an online role-playing game [17].

4.5 Overall Assessment of Engineering Innovation in Healthcare

Engineering innovation can make important contributions to some of the key objectives of healthcare: improving the quality, safety and efficiency of care; promoting a shift to preventive and personalised care; and improving the availability of long-term care [18]. Such innovation holds many opportunities and challenges for individual engineers and commercial engineering enterprises. The likely long-term growth in the importance of such innovation also suggests that changes in engineering education may be required.

Among the most attractive of challenges for individual engineers are the opportunities that healthcare offers for innovation with much closer interaction with beneficiaries than is usual in the profession. This will require engineers to focus more specifically on the diverse needs of each person rather than the benefits

[3] Dr. Aslak Jøssang, private communication.

to entire communities. This demands sensitivity, an imaginative anticipation of the variety of human needs and of the variety of responses to technology, and a willingness to consider responding to the unexpected. As an example of the latter, one respondent in a study of the desirable features of 'social robots' wanted 'something he could shout at, and that would know he was shouting at it' [19], a comment which raises an interesting combination of ethical and metaphysical questions.

Demographic studies of Western countries give the expectation of increasingly aged populations. Some studies also report an envisaged future shortage of healthcare personnel. These factors suggest that engineering innovation in healthcare may offer good future business opportunities for commercial enterprises. However, such enterprises need to remain alert to the broader societal dialogue about the ethics of care for the aged. Caring for an ageing population and a shortage of appropriately trained staff are societal issues that may be resolved by means other than a 'technological fix'. For example, it may be ethically unacceptable to use increasingly impersonal automated systems in the care of the elderly whilst a large part of the population is unemployed but capable of providing truly personal care following appropriate training. Indeed, assessment of the benefits of engineering innovation in healthcare requires exercise of all of the engineering virtues in close collaboration with medical personnel, as there may be powerful political and commercial influences at work. For example, the findings of a large scale UK study of telehealthcare show many nuances: particular interventions may be successful, but this depends on many factors. Even so, the UK government has become a forceful advocate of the widespread use of such technology due to its overriding determination to reduce the costs of healthcare [20, 21].

Engineering education teaches how knowledge of science and mathematics may be combined with imagination, reasoning, judgement and experience to provide practically useful outcomes. The science content of such education is predominantly physics and chemistry, with some attention to aspects of biology. Effective engineering in healthcare will still need this science base, but also a much greater range of biological knowledge, including especially anatomy and physiology, and in some instances neurology. Knowledge of psychology will also be important, to give understanding, for example, of the variety of human responses to technology and of how human expectations change during a lifetime. However, the greatest change needed in engineering education is most likely to be in the significance of the teaching of ethics. Individual engineers have often been somewhat protected from the need for continuous ethical alertness by the diffuse nature of ethical responsibility in the large organisations in which they have typically worked and by the distance, in time and place, between their engineering activities and the beneficiaries of those activities. Such diffuseness and distance are greatly reduced in healthcare engineering. Healthcare engineers will need to be

[3] Dr. Aslak Jøssang, private communication.

taught to prioritise persons rather than technology, in the same way that doctors are taught to prioritise the treatment of persons rather than their diseases.

There are certainly as yet unrecognised opportunities and challenges in engineering innovation in healthcare. For example, the aged, though they have diminished physical and mental functionings, remain persons. Hence, their care should seek to promote their wellbeing, agency and truly human relationships. Furthermore, the aged are also toward the end of their lives, a time of special personal significance. Thus, it is important to use healthcare engineering in ways that do not hinder reflection on the meaning of the apparent end of such personal existence. Perhaps engineering may even be used to create an environment that promotes such reflection. Whether or not this particular suggestion is viable, we should always bear in mind the challenge to all engineers: to match the great possibilities for technical innovation in engineering with a corresponding innovation in the imaginative acceptance and expression of ethical responsibility.[4]

4.6 Transport and Health

The increase in prominence of engineering activities in healthcare leads to a need for a reassessment of the activities, roles and priorities of engineers. Paralleling this entanglement of engineering with healthcare is an increased awareness by the medical profession of the effects of engineering policy and activities on health. Hence, it is pertinent to ask if engineering can learn from such medical awareness. As an example of the potential benefits of considering such awareness, this section will consider the topic of transport.

4.6.1 Engineering and Transport

Transport is a core engineering activity, particularly involving the work of civil engineers and mechanical engineers. Civil engineering is essential for the planning, design, construction and management of transport infrastructure. Planning involves forecasting the transport needs, including the number of likely trips, their destination and route and the mode of transport that will be used. Designing transport systems involves the sizing of facilities and specification of the technical aspects of their physical construction. Management of transport infrastructure involves ensuring that vehicles move as planned through appropriate use of signage and controls, increasingly using advanced electronic information and control systems. Safety of passengers is a key aspect of all these activities, and attention is also given to control of detrimental effects such as noise and vibration.

[4] An earlier version of Sects. 4.2–4.5 appeared as part of [22].

Mechanical engineers are particularly concerned with the design, construction and operation of the vehicles that use the transport infrastructure. The UK Institution of Mechanical Engineers (IMechE) summarises its perception of the issues involved in the following terms: ‘Safe, efficient transport systems with less congestion and emissions’, and ‘In the UK we have an insatiable appetite for mobility—we view it as a human right. Yet the transport sector is damaging our environment—transport produces over a quarter of UK CO_2 emissions. These policy statements discuss possible engineering solutions to the dual requirements of increased mobility and lower emissions’ [23, 24]. IMechE has produced such policy statements and reports on a number of issues, including intelligent transport systems, low carbon transport, electric vehicles, life cycle analysis, road pricing, freight and the need for an additional runway at Heathrow airport. These all show a great concern for balancing a need for increased mobility with the need to reduce CO_2 emissions. Particular note is taken of the contribution of good transport systems to the UK economy, especially the automotive industries, ‘Employing 850,000 people, with a turnover of £50 billion and producing some 1.5 million cars annually, the UK’s automotive sector has a global reputation for research and development, design engineering and manufacturing’ [25]. These policy statements and reports are predominantly technical in content, though some also give prominence to the need to promote social change: ‘Traffic in the UK has increased by 81 % in the last 25 years and is continuing to rise. The resultant congestion has serious impacts on the economy, our quality of life and overall emissions from transport. Something needs to change. Many have argued that we now need a pricing mechanism that effectively internalises the real environmental and economic cost of road use. Such a system would take account of distance travelled, type of road used, relative congestion and the time in which the road user travelled’ [26]. This shows a concern to ameliorate the deleterious effects of road transport on quality of life, but essentially within the existing transport infrastructure.

4.6.2 Healthcare and Transport

The UK British Medical Association (BMA) has recently published a detailed report assessing current transport provision and its effects on human wellbeing, *Healthy Transport = Healthy Lives* [27]. The report recognises that transport is an essential activity that has many social benefits and that the connectivity that it provides is essential for a modern economy. However, it raises serious questions about the effects of the way such connectivity is provided on health: ‘as the UK transport environment has become increasingly complex, transport’s impact on health has become unnecessarily harmful; to the point where it is a significant cause of morbidity and mortality… The number of car users continues to increase, numbers walking and cycling have stagnated, and changes to the built environment continue to prioritise the ability to travel, rather than the ability to reach destinations. All of which mean that the health of the nation continues to suffer’ [28].

Thus, the BMA is in agreement with the IMechE that excessive road transport is a major transport issue in the UK, but the BMA's emphasis is primarily on health impacts: 'The level of UK car use negatively impacts on health as a result of physical inactivity, road traffic injuries, air and noise pollution and the loss of the street as a social space' [29]. The report provides detailed assessment of these impacts, such as: the 208,648 reported road casualties in 2010, including 1,850 killed and 22,600 seriously injured (about a fifth of all killings and serious injuries in the UK), with about a third aged under 16 years; that air pollution is associated with 50,000 premature deaths a year; and that excessive noise causes seriously adverse effects on the physical and mental health of adults, and is particularly associated with cognitive impairment in children. Excessive road transport also increases health disparities as those living in deprived areas are most likely to live close to the busiest roads. Such roads may also disrupt contact between parts of those areas. Additionally, those on low incomes will not have access to privately owned vehicles and are therefore deprived of access to essential services and leisure activities. Furthermore, the independence of children is greatly reduced as potential social spaces are unhealthy and unsafe.

However, the BMA's emphasis on the wellbeing of persons leads to more radical proposals for reforming transport provision. It assesses that the current transport provision overemphasises mobility, the *ability to travel*. This it partly attributes to government policy focusing on expanding the automotive industry rather than prioritising the health of the nation. It proposes instead that planning decisions should give greater attention to the *ability to access* services and destinations. Furthermore, wherever possible the BMA proposes that such access should be by means of *active transport*, such as walking and cycling. The report details the recognised health benefits associated with such active transport which include: improved mental health (improved self-esteem and mood, and reduced anger, depression and anxiety), a reduced risk of premature death, maintenance of a healthy body weight and prevention of chronic diseases such as coronary heart disease, stroke, type 2 diabetes, osteoporosis, dementia and cancer.

There is a great potential for change, for nearly a quarter of all car journeys in the UK are within one mile and two-fifths are within two miles, distances easily covered on foot or by bicycle. However, there are psychological barriers, for evidence shows that people overestimate the time taken to walk between locations, and underestimate the time to do the same journey by car. For longer journeys, public transport is regarded as active transport, for this almost always incorporates a period of walking. Overall, this leads to a hierarchy of proposals for sustainable, health-promoting transport: (i) reduce demand for motorised transport by a range of measures, including good spatial planning of the urban environment; (ii) a modal shift to more sustainable modes of transport, including walking, cycling and public transport; (iii) efficiency improvements in existing modes of transport, including sharing of private vehicles, improved public transport and technically improved vehicle efficiency; (iv) as a last resort, selective and sustainable capacity increases for powered transport [30].

4.6.3 Reconsidering Engineering and Transport

Both the IMechE and the BMA make cogent proposals for the future of transport in the UK. Both identify the great increase in road traffic as being one of the most pressing problems needing attention. However, there is a significant difference in emphasis in their analysis of the problem and of the best way forward. The IMechE gives priority to maintaining mobility, the ability to travel, and focuses mostly on technical and fiscal means for ensuring this mobility broadly within the existing transport infrastructure. This is coupled with a great concern for reducing CO_2 emissions and an awareness of the detrimental effects of excessive road transport on quality of health. In contrast, the BMA gives priority to the ability to access services and destinations by means of active transport, with a great emphasis on the very substantial health benefits of such an approach. This is coupled with a concern for transport that promotes social inclusion and social interaction, with strong support of public transport for longer journeys.

These differing approaches may be considered in terms of the description of the practice of engineering given in Chap. 2. It would seem that the BMA proposals come closest to an approach that considers the goal of engineering as being *the promotion of the flourishing of persons in communities through contribution to material wellbeing*. An emphasis on health is an important part of such flourishing, but the BMA approach also gives appropriate attention to other aspects of well-being such as the provision of agreeable social spaces and the promotion of interpersonal interaction. The IMechE approach rather emphasises a particular aspect of human flourishing, the ability to travel. Both approaches allow the expression of internal goods, but the focus on the person-friendly local environment inherent in the BMA approach is especially relevant to the paramount broad internal good of safety.

From an engineering safety viewpoint, roads are highly anomalous. Modern, engineered industrial processes pay great attention to the shielding of operators from potentially dangerous moving parts and from harmful emissions. Such considerations are not rigorously applied to roads, and even more astonishingly, in many urban areas they are the only outdoor spaces available for children to play. Engineering of cars is now such that most occupants, if appropriately restrained, will survive a collision at 50 km an hour, whereas there is an 80 % risk of death for pedestrians involved in a collision at such a speed [31]. Even modest changes in use and design can be beneficial. For example, the introduction of 20 mph (32 km an hour) traffic speed zones in London was associated with a 41.9 % reduction in road casualties. The percentage reduction was larger for children, 48.5 %, and also larger for the category of killed or seriously injured casualties than for minor injuries. Casualties also fell by 8.0 % in areas adjacent to 20 mph zones [32]. Setting of lower speed limits needs to be coupled with changes to the engineering design of roads so as to promote speed compliance. Road systems also need to be engineered to promote safe walking: convenient pavements and pathways are too often non-existent, discontinuous, not sufficiently separated from motorised traffic and poorly maintained. Furthermore, the resurgence of interest in bicycle design, noted in Chap. 1, needs to be complemented by serious commitment to the construction of bicycle tracks that are safely separated from other traffic.

With regard to external goods, the two approaches have differing emphases. The IMechE takes particular note of the contribution of the automotive industry to the UK economy. The BMA recognises the economic importance of connectivity, but suggests that government promotion of the automotive industry has been to the detriment of the nation's heath. In general, the BMA emphasis on the ability to access services and destinations gives greater priority to the agency of beneficiaries than does a narrower emphasis on an ability to travel. Prioritisation of an ability to access by active transport is certainly of greater benefit to the economically deprived and to children. Exercise of the engineering virtues is important for both the IMechE approach and the BMA approach, particularly as this is a subject, like telehealthcare, on which the UK government makes major commitments without prior full assessment of the available knowledge [33]. Indeed, all the engineering virtues of accuracy and rigour, honesty and integrity, respect for life, law and the public good and responsible leadership, listening and informing are pertinent to transport. Listening to other sources of expertise, such as healthcare professionals, is particularly important for engineers in this case.

4.6.4 Transport and Health: A Global Issue

Although the discussion so far has been concerned with the UK, issues of transport and health are serious global issues. For example, a recent report has concluded that car use in the 27 European Union member states is subsidised ('externalised') by between 258 and 378 billion Euros each year, or about 520–750 Euros for every inhabitant. Such externalisation results in excessive noise emissions, greenhouse gas emissions and other losses of quality of life. Such externalisation is particularly unfair to groups such as those who do not own cars, residents along major roads, children and future generations. This report recommends that these costs should be internalised into transport prices as a mechanism to reduce the excessive and inefficient use of car transport in the EU [34]. It also highlights the inadequacy of looking for technical fixes to problems such as greenhouse gas emissions without considering broader economic and societal factors, including approaches to land use and behavioural change. The report further considers that transport is an issue where the perspective of an individual and the perspective of society may be very different. Thus, an individual with a means of transport may gain great benefit from each journey undertaken. However, the negative effects of such a journey, such as noise and pollution, are borne by society at large, including the future members of that society. Such potential conflict provides further support for the BMA emphasis on *ability to access by active transport*, where the individual benefits at much lower cost to society. Such an emphasis also has greater potential for meeting the engineering goal of *the promotion of the flourishing of persons in communities* without unfairly disadvantaging any individual or group.

According to the findings of the *Global Burden of Disease Study 2010*, air pollution is now one of the top ten causes of fatal illness worldwide. Pollution from cars has become an especially serious issue in many Asian cities due to a rapid increase in ownership and use. It is estimated that 2.1 million people, mostly in China and India, died prematurely in Asia from air pollution in 2010, with a major cause being fine particles and gases emitted by cars and lorries [35, 36]. The full effects of such pollution on health and fatality in these cities may not be known for many years due to the long latency of many associated diseases, including cancers.

Air pollution and the resulting ill health and premature death are unwanted consequences of great technical innovation in the engineering of powered vehicles. The minimal ethical challenge to engineers is now to collaborate with others to devise built environments and transport systems that diminish such unwanted effects. The aspirational ethical challenge to engineers is to collaborate with others to devise built environments and transport systems that actively promote the health of persons and their communities.

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Chapter 5
Engineering for Development

5.1 Introduction

Billions of people around the world suffer from extreme poverty. Such poverty is characterised by hunger, sickness, lack of shelter and clothing, low incomes, low achievements in education, vulnerability, voicelessness and powerlessness. The causes of such poverty are many, and include political, social, economic and environmental factors. International organisations, governments and non-governmental organisations that are involved in ameliorating such poverty tend to focus on political and economic remedies. However, engineering has a very important role to play for it can provide practical solutions to the needs of people suffering from extreme poverty. As such poverty is a major injustice, it presents a clear case of an *opportunity of professional capabilities* for engineers, of the type described in Chap. 2. Indeed, as the consequences of extreme poverty are so appalling, it may better be considered an *obligation of professional capabilities* for engineers.

To provide an example of the nature and magnitude of the issues, this chapter will first consider the role that better provision of energy can play in the amelioration of poverty. Energy is a key enabler: all countries that have moved their populations out of poverty in modern times have done so whilst greatly increasing access to a diversity of energy supplies, replacing human and animal labour with more powerful energy sources. Furthermore, such energy provision requires the collaboration of many different types of engineers, including civil engineers, mechanical engineers, electrical engineers and chemical engineers. It is, therefore, a need to which large numbers of the profession can contribute. Second, some of the many other ways in which engineering can contribute to the amelioration of extreme poverty will be outlined. Third, ways in which individual engineers and engineering institutions can contribute, and the benefits of doing so, will be considered using the ethical framework for engineering developed in Chap. 2. Finally, some valuable lessons that may be learnt from African approaches to ethics will be highlighted.

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5.2 Energy, Poverty and Development

Modern energy sources provide a crucial underlying basis for the promotion of human flourishing. Nevertheless, the link between poverty and energy provision has received much less attention than the links between poverty and the provision of food, clean water, sanitation and shelter. The effects of poor availability of energy are less immediately apparent than the effects of these other basic goods. However, on a global basis, 1.3 billion people are without access to electricity and 2.7 billion are without clean, safe cooking facilities. More than 95 % of these are in sub-Saharan Africa or developing Asia and 84 % are in rural areas. Sub-Saharan Africa is home to 12 % of the global population of which 45 % are without access to electricity. Over 1.9 billion people in developing Asia rely on traditional biomass for cooking, including around 840 million in India and 100 million in each of Bangladesh, Indonesia and Pakistan. A further 400 million people, mostly in China, rely on coal. Even in oil-rich Nigeria there are over 90 million people without access to clean, safe cooking facilities [1]. This lack of modern, safe energy sources has many dire consequences. Just to give one example, it is estimated that cooking on open fires in poorly ventilated or inefficient stoves fuelled with traditional biomass results every year in sub-Saharan Africa in about 360,000 premature child deaths (under 5 years of age) and about 23,000 female deaths (over 30 years of age), from pneumonia and chronic obstructive pulmonary diseases respectively [2]. Global premature deaths due to smoke from such biomass currently exceed those from either malaria or tuberculosis.

Hence, it is particularly important to consider the benefits of appropriate access to energy. Provision of energy is an excellent example of how engineering enables human wellbeing and agency. In the context of extreme poverty, such enablement can be considered in terms of the United Nations Millennium Development Goals. These were established at the UN General Assembly Millennium Meeting in 2000 in recognition of the need to speed up poverty alleviation and socio-economic development. Here are some of the contributions that better energy availability can make to achieving these goals [3]:

Eradicate extreme poverty and hunger Access to reliable energy enables enterprise development; lighting permits income generation beyond daylight hours; machinery increases productivity; energy can often be provided by small-scale locally owned businesses, creating employment; 95 % of staple foods (such as rice, grain and green bananas) need cooking before they are eaten and need water for cooking; improved productivity throughout the food chain, including transportation of food to areas of need; reduced post-harvest losses through better preservation; better irrigation and hence improved food yields; better access to clean water; reduction in proportion of income spent on energy.

Achieve universal primary education Creation of a more child-friendly environment (clean water, sanitation, lighting, space heating/cooling); freeing of children's, and especially girls' time from helping with survival activities (gathering firewood, fetching water); lighting permits home study; lighting in schools allows evening classes and helps retain teachers, especially if their accommodation has electricity; electricity enables access to educational media that allow distance learning; electricity allows use of teaching aids such as projectors and computers; modern energy systems and efficient building design reduce heating/cooling costs.

Promote gender equality and empower women Freeing of girls' and young women's time from survival activities (gathering firewood, fetching water, cooking inefficiently, crop processing by hand, manual farm work); lighting permits home study and allows evening classes, giving better access to education; street lighting improves women's safety; reliable energy services increase scope for women's enterprises.

Reduce child mortality Reduction of the indoor air pollution that contributes to respiratory infections that account for up to 20 % of child deaths; reduction in the need for gathering and preparing traditional fuels that exposes children to health risks and reduces time spent in child care; modern energy leads to fewer burns, accidents and house fires; provision of nutritious cooked food, space heating and boiled water contribute to better health; cold chain provision allows access to vaccines.

Improve maternal health Access to better medical facilities for maternal care, including medicine refrigeration, equipment sterilisation and operating theatres; reduction in excessive workload and heavy manual labour improves health of pregnant women; improved production and distribution of sex education literature and contraceptives; access to distance medicine; improved provision of cooked food, space heating and boiled water.

Combat HIV/AIDS, malaria and other major diseases Electricity in health centres enables night availability, helps retain qualified staff and allows equipment use; refrigeration allows vaccine and medicine storage; safe disposal of used hypodermic syringes by incineration prevents re-use and potential further spread of HIV/AIDS; enables development, manufacture and distribution of medicines and vaccines; allows access to heath education media.

Ensure environmental sustainability Increased agricultural productivity is enabled through the use of machinery and irrigation, which reduces the need to expand the quantity of land under cultivation, reducing pressure on the ecosystem; substitution and improved efficiency reduces erosion, reduced soil fertility and desertification due to traditional fuel use; encouragement of better natural resource management and reduced local pollution; facilitates rural non-farm-based enterprise and processing of non-timber forest products.

Develop a global partnership for development Energy is essential for most of the cooperative international, governmental, non-governmental and commercial activities that can promote development.

Overall, provision of appropriate access to energy can be a very effective means of contributing to human flourishing in developing countries. However, a number of mistakes have been made in past energy projects and policies, including [4]: prioritising technology development over delivering energy as a service to the poor; failing to understand the links between energy and livelihoods, including in relation to development and poverty reduction strategies; lack of awareness on the part of non-energy specialists of the role energy plays in meeting objectives in sectors such as agriculture, health, education and manufacturing; lack of attention to the energy requirements of community facilities, schools, medical centres and micro-enterprises; overemphasis on energy supply issues in relation to end-use benefits, represented in the funding bias towards large power projects over capacity building at local level to install, operate and maintain small-scale systems; one-directional planning of energy projects, often ignoring the need to involve communities in the planning process, resulting in projects that are not socially acceptable, sustainable or appropriate to the needs of a given location. That is, many past projects have prioritised technology rather than people.

However, approaches are now being proposed that focus first on understanding the effect that availability of energy has on peoples' wellbeing and agency. The provision of energy can then be designed to ameliorate the constraints on such human flourishing. Key features of such a people-centred approach include [5]:

- Reaching beyond technical issues, to deliver energy provision that meets people's needs and priorities. That is, provision of supply should be designed around the benefits that energy can provide.
- Being aware of subjective and social benefits. Access to electricity promotes a sense of inclusion in modernising processes. Energy for transport and communication allows poor people to maintain contact with their extended family and friends.
- Ensuring that communities have a voice in the decision making process on how to meet their energy needs. That is, planning should include substantial bottom-up participation.
- Working across all sectors (including agriculture, health, education and manufacturing) to integrate energy more fully into development processes from early on. Energy is a vital enabler in meeting the goals of these sectors.
- Working at local, national and international levels, in order to develop pro-poor policies based on real evidence of the impact of energy availability on poor people. Provision of energy needs to be given a priority comparable to those given to provision of food, clean water, sanitation, shelter and medical services.
- Taking a holistic approach to energy across sectors rather than a project-based approach. Diverse sources of energy are needed, including appropriate use of traditional sources.
- Building a deeper understanding of the links between energy availability and poverty reduction. This should include assessment of the effects of energy availability on rural to urban migration, the effects on empowerment and inclusion (especially for women), and the effects on the reduction of drudgery.

A great variety of technologies are in principle available, but these are only practically useful if they are available locally at an appropriate price. Some are simple, cheap and effective, such as improved stoves and solar water heaters that can be manufactured locally. Local development and manufacture of small-capacity off-grid equipment for the provision of electricity can also be effective, such as micro-hydro turbines, small wind turbines and biogas digester systems. These can be very useful in remote locations. At a village or district level, mini-grids can provide electricity with loads up to 500 kW. For urban areas, large-scale thermal or hydro electricity generation is necessary. Such sources are important for businesses as well as for individuals. For example, many major companies in Nigeria provide their own electricity through diesel generators. The high cost of such energy supply has been a key factor in limiting the competitiveness of Nigerian industrial production and hence of employment [6].

An assessment of the balance of differing scales for supply of electricity is important. An International Energy Agency (IEA) projection regards grid extension as being the most suitable for urban areas and for about 30 % of rural areas, but not cost-effective for more remote rural areas. Therefore, it is projected that 70 % of rural areas should be connected either with mini-grids (65 % of this share) or with small, stand-alone off-grid supplies (the remaining 35 %). Most of the mini-grid and off-grid provision is projected to come from renewables [7]. Such smaller scale provision can ease the difficulty of finding the funds needed for capital investment, though modern renewable technologies tend to have relatively high initial capital costs and relatively low recurrent costs.

The IEA has carried out detailed studies of the costs of providing modern energy access, defined as 'a household having reliable and affordable access to clean cooking facilities, a first connection to electricity and then an increasing level of electricity consumption over time' [8]. Here clean cooking facilities refers to biogas systems, liquefied petroleum gas (LPG) stoves and advanced biomass stoves that have much lower emissions and higher efficiencies than traditional fires. The initial electricity consumption for rural households was assumed to be 250 kWh per year, and 500 kWh per year for urban households. The IEA considered the period 2010–2030, with electricity consumption of newly connected households rising to 800 kWh per year by 2030, a level seen in much of developing Asia. These are relatively modest amounts compared to present Western levels, though the figures do not include provision to businesses and public buildings such as schools and hospitals. It was estimated that to provide universal modern access at these levels would require investment of US$ 48 billion each year, on average. This greatly exceeds the estimated US$9.1 billion that was invested globally in extending access to modern energy provision in 2009. However, these are small amounts compared to global weapons sales of US$411 billion and world military expenditure of US$1,738 billion in 2011 [9]. As for the case of provision of clean water and sanitation considered in Chap. 2, many deaths and much suffering could be avoided, and human flourishing greatly promoted, by the diversion of relatively small amounts of the budget for the preparation for war to the supply of essential energy resources to the poorest of the world's population. The IEA estimates that achieving universal access by 2030 would increase global electricity generation by 2.5 %. The demand for fossil fuels would be expected to rise by 0.8 % and CO_2 emissions would increase by 0.7 %, figures it considers trivial in relation to energy security or climate change. The benefits would be a major contribution to social and economic development and a contribution to avoiding 1.5 million premature deaths per year. The provision of such energy resources can be seen as a clear opportunity of professional capabilities for engineers.

5.3 Engineering, Poverty and Development

Energy provides just one example of the many ways in which engineering can contribute to the alleviation of extreme poverty. An important part of this contribution has been summarised in the following way by Calestous Juma, Chair of the UN Millennium Project Science, Technology and Innovation Task Force:

> At least three key factors contributed to the rapid economic transformation of emerging economies. First, they invested heavily in basic infrastructure, which served as a foundation for technological learning. Second, they nurtured the development of small and medium-sized enterprises, which required the development of local operational, repair and maintenance expertise. Third, their governments supported, funded and nurtured higher education institutions, academies of engineering and technological sciences, professional engineering and technological associations, and industrial and trade associations [10].

The importance of these factors has also been identified by David King, Chief Scientific Advisor to the UK Government:

> The key to sustainable development in Africa—that is, development that does not rely indefinitely on foreign aid—is the creation of infrastructure. Part of this is a purely physical matter: a question of civil engineering. The business and finance communities in African nations identify the lack of good roads, railways, air and water transport facilities, energy and water supplies, and telecommunications networks as one of the main obstacles to economic growth [10].

As already noted, it is not only civil engineering but all of the main branches of engineering that have a role to play in such development, and not only in Africa. Furthermore, quantitative data is available to support these contributions from countries that have been very successful in removing people from extreme poverty, such as China. China initiated major economic and agricultural reforms in 1978. From 1985, a high priority was given to road development. A major part of this involved the development of expressways, with the total length increasing from 147 km in 1988 to 25310 km in 2002, an average annual growth rate of 44 %. In contrast the length of minor, mostly rural, roads increased by only 3 % each year in the same period. However, a detailed study has shown that investing in such minor roads was a much more cost-effective means of raising both rural and urban poor out of poverty. Moreover, there was a complex trade-off between economic growth and poverty reduction for different regions of China. Road investments yielded the highest economic benefits in eastern and central regions, whilst the contribution to poverty reduction was greatest in the southwest region. This indicates that the investment strategies for economic growth are not necessarily the same as those for poverty reduction, even within the same country [11].

The contribution that engineering can make to poverty reduction and sustainable development is belatedly being recognised by governments and international agencies. For example, in 2010 UNESCO published its first report on engineering, the first ever report on engineering at an international level, with a focus on development [12]. This valuable report consists of short, expert accounts of the many contributions which engineering can make. In particular it identifies the need to:

- Develop public and policy awareness and understanding of engineering as the driver of social and economic development.
- Develop information on engineering, highlighting the urgent need for better statistics and indicators, such as how many and what types of engineer each country has.
- Transform engineering education to emphasise the social relevance and problem-solving nature of engineering.
- More effectively innovate and apply engineering to global issues such as poverty reduction, sustainable development and climate change.

More particularly, there is a need for engineers of all sub-disciplines to take an active role in poverty reduction and sustainable development. The next section seeks to provide a basic understanding of why this is so and also seeks to indicate ways in which such action may be promoted.

5.4 Engineering, Poverty and Development: An Ethical Analysis

In Chap. 2 it was noted that the UK Royal Academy of Engineering describes the purposive *social ends* of engineering as being 'to enhance the welfare, health and safety of all whilst paying due regard to the environment and the sustainability of resources'. As was discussed, this is a very demanding description. In order to begin an identification of the means of enhancement, a working definition of the *goal* of engineering was proposed: *the promotion of the flourishing of persons in communities through contribution to material wellbeing*. Such flourishing was taken to include both *wellbeing* (such as welfare, health and safety) and *agency*, the possibility to advance whatever goals and values that a person or community has reason to advance. However, there are very many ways in which individual engineers and engineering institutions may seek to fulfil this goal. Hence, it was proposed that a useful guide for the choice of such actions may be formulated in terms of an *opportunity of professional capabilities*: 'if some action that can be freely undertaken is open to a person (thereby making it feasible), and if the person assesses that the undertaking of that action will create a more just situation in the world (thereby making it justice-enhancing), then that is argument enough for the person to consider seriously what he or she should do in view of these recognitions'. It was also suggested that sometimes the circumstances of persons and communities may be so dire, and the capabilities of engineers so apt, that it is more appropriate to consider an *obligation* of professional capabilities.

Extreme poverty is the daily reality of very many of the world's people: 'Even without the effects of hurricanes, floods, earthquakes and landslides, the immediate prospects for both the urban and rural poor in many parts of the world are bleak, with little or no access to even the most basic of infrastructure, education and healthcare, and with little, or at best tenuous, legal tenure to land or property' [10]. That this is a situation of major injustice, that engineers have the skills to ameliorate this injustice, and that this gives rise to at the very least an opportunity of professional capabilities, provide the basic motivations for taking an active role in such poverty reduction.

It was noted in Chap. 2 that the description of such an opportunity of professional capabilities is practical rather than idealistic, for it concerns the serious consideration of feasible options and thus recognises that there may be situational constraints on the action of any individual engineer. However, some engineers take this opportunity so seriously that they seek employment in organisations that specifically work to alleviate extreme poverty, such as NGOs like Practical Action, Engineers Without Borders, Engineers Against Poverty and Water Aid, governmental or international agencies, or commercial enterprises operating in developing countries. Many thousands of engineers are involved in such work and they make very substantial contributions to the relief of extreme poverty. The following analysis will show how the characteristics of such work fit the proposed ethical account of engineering. Such engineers show by their activities that they have already been convinced of the ethical case for such practical action. However, the analysis also seeks to show how all engineers have the capabilities to contribute to the alleviation of poverty, even if they are not able to work directly and exclusively on such issues.

The *internal goods* of engineering include the satisfaction arising from finding ingenious solutions to problems through the use of reason, imagination, judgement and experience. In developed countries this may often involve the design, manufacture and use of technically sophisticated artefacts. In developing countries there may rather be an emphasis on 'simpler' technologies, due to financial constraints and the need to provide solutions that make use of locally available materials and local manufacturing skills, and that can be maintained locally. However, finding such 'simpler' solutions may itself require great ingenuity and result in considerable satisfaction: the term 'simpler' is rather misleading. Similarly, the internal goods of safety, cost-effectiveness and sustainability remain very important in developing countries, though the challenges that they present will vary with circumstances. Perceptions of risk depend on the local, physical and social environment and on local culture. Cost-effectiveness depends on the ability of people to pay. In areas of acute poverty, it is the relief of human suffering that needs prioritising rather than long-term sustainability: for example, 'brown sustainability' might have to replace 'green sustainability' in the immediate term in slum areas [13]. Furthermore, great satisfaction can arise from the need to work closely with local people and from the clear benefits that arise when work is completed. The importance of such subjective internal goods was well expressed by a civil engineering student, Carolyn Maphanda, who volunteered to work on a project to build low-cost housing in South Africa: 'I learned that building is not all about having completed the job, but also about thinking about the people who will be using the structure on a daily basis' [14]. Indeed, this is a valuable lesson for all engineers wherever they are working.

MacIntyre's characteristic examples of *external goods* were power, prestige and wealth. Engineers rarely achieve power. The few engineers who gain prestige or great personal financial rewards on account of their professional work tend to be those involved with great technical sophistication or iconic projects. However, engineers certainly contribute greatly to the economic development of the communities in which they work. Nevertheless, as has been noted for the case of road building in China, the maximisation of economic benefits is not necessarily directly associated with the maximisation of poverty relief. The most obvious characteristic external goods of engineering are technological artefacts. There are several different approaches to selecting technology for the alleviation of poverty [15]. The first to be adopted was the transfer of existing technology from developed to developing countries. In this case a key question has been whether it is possible to transfer technology at an appropriate scale, with modification sometimes necessary to make smaller scale options. This was followed by the development of 'appropriate technologies' specifically designed for impoverished people in developing countries. Later, the importance of the participation of users in technology development was emphasised. More recently, there has been an emphasis on people and their situations and what is described as people's technological capabilities. These latter approaches are those that were most central to the people-centred approach to electricity that has been outlined.

However, engineering is essentially an enabling profession and the greatest benefits are apparent in the improved capabilities of the beneficiaries: as their *wellbeing* improves so does their *agency*, the ability to advance personal goals and values. When a technology becomes available at a reasonable cost its use may be rapidly adapted in ways that meet local needs in unexpected ways. This has happened with mobile phones in Africa [16]. More people in Africa now have a mobile phone than have access to electricity: there are an estimated 700 million SIM cards on the continent. Mobile phones overcome some of the problems of poor transport infrastructures, poor electricity infrastructures and sparsely populated rural areas. Basic phones with long battery life are most popular. 'Mobile money' is one of the most important innovations: money can be sent between mobiles to pay for goods and services, and when necessary cashed out at agents. The continent accounts for four-fifths of such transactions on a global basis. Mobile phones are also bringing much higher degrees of transparency and information sharing, both of which can assist the alleviation of poverty. For example, mobile phones allow farmers to cheaply and quickly check the prices that they can expect for their products at market. Such use of mobile phones shows that even 'sophisticated' technology can benefit impoverished people when available in a convenient form and at an affordable price.

Thus, all engineers need to be alert to the potential contributions of their work to development, with the potential for meeting human needs and for providing profitable business opportunities. However, attitudes of openness and humility may be necessary for it has been observed that in some cases, 'the people who invent a technology—in the sense of determining its use and making it viable—are not so much the engineers who design it as the consumers who discover what it's really for' [17]. This observation was made with reference to SMS, text messaging, which was initially created to transport short messages (160 characters) on the signalling paths needed to organise mobile phone telephony during periods when such control channels were quiet. SMS texting was little used for many years, and only became widely used when mobile phones became cheap enough for teenagers to own. It could be argued that it was teenagers who invented SMS. It is now available to the estimated 4 billion people who have mobile phones, including many in developing countries. This has led to the conclusion that, 'we need to stop being dazzled by the tech *sensation du jour*…and focus instead on something mundane that really works, reaches everyone, provides valuable services for poor people, exploits nobody and is based on a sustainable business model' [17].

The cultivation and exercise of the characteristic engineering *virtues* is especially important in work in developing countries as many of the checks, balances, social arrangements and supporting legal frameworks that are familiar in more developed societies may not be apparent. For example, an expert on the implementation of water and sanitation programmes has observed:

> A common problem with rural water projects is that the social infrastructure is not there to maintain them. The engineers who build them try to solve the problem by setting up village water committees, barefoot pump mechanic systems and other such arrangements, often unaware that they are establishing the embryo of local government—something that took 100 years in Europe, and requires anthropological understanding and political skills that do not usually appear on the engineering curriculum [18].

The virtues of *accuracy and rigour* remain crucial to the technological aspects of work. Engineers may need to be particularly alert to ensuring that they are working fully within their range of competence, for there may be fewer opportunities for seeking advice from knowledgeable colleagues if they are working in a remote environment. However, internet availability may allow more ready access to expertise, allowing engineers to share their experience wherever they are. One of the most important issues relating to *honesty and integrity* concerns the effective governance of infrastructure projects, especially relating to corruption [19]. Engineers are involved with many of the processes in which corruption can occur, including contract preparation, design, procurement, supply chain management, project management and maintenance. There are now a number of international and national initiatives, often led by professional engineering institutions, which seek to reduce corruption. An example is the UK Anti-Corruption Forum, an alliance of UK business associations, professional associations, civil society organisations and companies with interests in the domestic and international infrastructure, construction and engineering sectors. The Forum's objective is to help create a business environment that is free from corruption. All engineers can support such work [20]. *Respect for life, law and the public good* requires awareness of and sensitivity to local, societal and cultural priorities. There may also be situations for which the local legal requirements are less demanding than those of the engineer's home country. Indeed, international companies are subject to differing regulations throughout the world. Such organisations will have codes of practice that require employees to follow the more stringent conditions if there are differences between the requirement of the code and local regulations. The need for *responsible leadership, listening and informing* is especially demanding in developing countries. In such locations the gap between the knowledge and skills of professional engineers and those of the general population may be significantly greater than in developed countries. Such a privileged position brings great responsibility to act in a way that serves the best interests of the community. Listening is especially important and may give unexpected results. For example, engineers promote initiatives for clean water and sanitation because of the health benefits. However, a study of why people in rural Benin decided to install a toilet in their homes showed that it had little to do with health and was more a concern with social status, convenience and security [21]. Knowledge of such motivations is clearly important for the effective work of engineers.

Engineering *institutions* can make a huge contribution to alleviating extreme poverty. It has been argued that the great power and influence of the commercial engineering sector provides it with an ethical imperative to act and that there is an increasingly convincing business case for such action. That is, if businesses align their activities with countries' or regions' development goals, they can enhance their long-term business interests as well as meeting their corporate and social responsibilities:

> The private sector will benefit directly if the Millennium Development Goals are achieved by having access to a healthier and better educated workforce, a more stable investment climate, and a reduction in the business risks that accompany poverty-related problems such as global insecurity, climate change and ethnic conflict. It will also benefit from the vast new markets that will be created by drawing the 4 billion people that currently live on less than US$2 per day into economic life [22].

Even so, not all business with developing countries is well meaning, one of the most notorious cases of bad practice being the sale by a UK-based company of a hugely expensive and inappropriate military air traffic control system to Tanzania, a case of a 'Blatant Absence of Ethics' [23, 24]. Unfortunately, this was not a single and isolated incident of such bad practice.

The engineering institutions involved in education and professional registration have a very significant role to play in providing the means for poverty alleviation. For example, a recent report has identified a chronic lack of indigenous capacity in engineering in sub-Saharan Africa [25]. This is especially so for public sector positions in rural areas. Even so, in some countries there are also notable levels of unemployment among engineering graduates indicating that engineers are graduating without the necessary skills and experience to be employable. Capacity building will need increased public investment in education and more partnerships between academia and industry. This could include partnerships in which commercial engineering enterprises invest in university education departments that are local to the areas in which they operate. Such partnerships can be promoted by the introduction of 'local content' regulations to ensure that knowledge and skills are transferred from foreign engineering companies to local engineers. Furthermore, strengthening of indigenous professional associations could ensure better standards of practice through more thorough procedures for the registration of engineers.

Additionally, engineers everywhere may contribute to such capacity building if proper recognition is given to the global nature of the engineering profession [26]. Thus, university engineering departments can include development and sustainability within the curricula of engineering degrees. Professional associations can include development activities in their work for the promotion of the profession and take initiatives to highlight issues such as the importance of development infrastructure and the need to promote ethical practices. Engineering employers can promote the concept of global engineering through the professional development, secondment, mentoring and partnerships of their staff. Practising engineers everywhere can also contribute to development by supporting campaigning organisations related to their expertise, such as the Alliance for Responsible Mining (ARM) [27]. Miners across the developing world encounter many hardships. Even those working for large international mining companies may have very poor working and living conditions. The many involved in small-scale artisanal mining experience an even more precarious existence, with little legal protection, many workplace accidents and low income. Nevertheless, such artisanal mining does provide work opportunities, and the aims of ARM include the promotion of better work practices, social and environmental responsibility and improved livelihoods. This includes ARM's initiative in Fairtrade and Fairmined standards for metals, developed with Fairtrade Labelling Organisations International, which seeks to do for artisanal miners what Fairtrade has done for many tea, coffee, cocoa and banana growers around the world. That is, to give miners a fair price for what they produce and to inform consumers of the source of the metals in their jewellery.

Finally, the amelioration of poverty provides great opportunities for the *systematic extension* of the practice of engineering. One of the key aspects of such extension was identified in Chap. 2 as: *can the great technical innovation of engineering be matched by a corresponding innovation in the acceptance and expression of ethical responsibility?* This chapter has identified many ways in which such acceptance of ethical responsibility could be expressed. In addition, the alleviation of poverty requires great technical ingenuity, especially regarding the provision of effective products and processes at a cost that can be afforded. Such alleviation of poverty thus provides opportunities for the full expression of the goal, goods, virtues and institutions of engineering.[1]

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[1] Further consideration of engineering for development is given in later chapters. Chapter 7 will consider the Chinese 'win–win' approach to development. Chapter 8 will consider development beyond the Millennium Development Goals.

5.5 Learning from African Approaches to Ethics

The approach to ethics on which the present book is based is rooted in a description of the experiences of persons living in communities, as presented in Chap. 1. This gave rise to the description of the goal of engineering as *the promotion of the flourishing of persons in communities through contribution to material wellbeing*. The starting point was Levinas's description of an ethical act as 'a response to the being who in a face speaks to the subject and tolerates only a personal response'. As was noted, Levinas's insight was developed to provide a profound account of ethics in communities by Dussel, who worked mostly in Argentina and Mexico. This emphasis on persons in community is also expressed in the Arabic concept of *Shakçânya,* referring to a 'communitarian self' [28], and by the Sanskrit expression *So Hum*, 'You are, therefore I am' [29]. These approaches stand in contrast to many Western approaches to ethics that tend to emphasise the autonomy of the individual.

Many African languages recognise our interdependence through concepts such as *ubuntu* in Nguni languages and *botho* in Sotho. These concepts are difficult to translate into English, but the idea of *ubuntu* is often rendered as 'A person is a person through other persons'. *Ubuntu* is a central concept in the thinking of Desmond Tutu, as he explains:

> It is the essence of being human. It speaks of the fact that my humanity is caught up and inextricably bound up in yours. I am human because I belong. It speaks about wholeness; it speaks about compassion. A person with *ubuntu* is welcoming, hospitable, warm and generous, willing to share. Such people are open and available to others, willing to be vulnerable, affirming of others, do not feel threatened that others are able and good, for they have a proper self-assurance that comes from knowing that they belong to a greater whole. They know that they are diminished when others are humiliated, diminished when others are oppressed, diminished when others are treated as if they were less than who they are….
>
> When we Africans want to give high praise to someone, we say, '*Yu, u nobuntu*': 'Hey, so-and-so has *ubuntu*'. A person is a person because he recognizes others as persons…*Ubuntu* does not say, 'I think, therefore I am.' It says rather: 'I am human because I belong. I participate. I share'….
>
> Africa has a gift to give the world that the world needs desperately, this reminder that we are more than the sum of our parts: the reminder that strict individualism is debilitating. The world is going to have to learn the fundamental lesson that we are made for harmony, for interdependence. If we are ever truly to prosper, it will be together [30].

This concept of *ubuntu* provides an excellent description of the ethical motivation that should underlie the ethical practice of engineering. It can apply wherever engineers carry out their work.

The concept of *ubuntu* demonstrates an attitude to others that is fundamentally relational. Cornel du Toit has argued that such a view of life with others, and with nature, contrasts with much Western thinking about nature, and others, which is fundamentally instrumental and focused on efficiency. For this reason he suggests that Africa may be able to give the world a lead in developing technology in a way that ensures the maintenance of the integrity of persons and communities:

'technology with a human face' [31]. However, this will require African development itself to take place in a way that protects the valuable traditional African community life with its values of caring, sharing, consensus and reconciliation. If engineers involved with development can take heed of this possibility, then Africa, and indeed other traditional communities around the world that still value real interpersonal cooperation, can offer an important example to the practice of engineering in the rest of the world.

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Chapter 6
Personal Responsibility and Supporting Social Structures

6.1 Introduction

The previous chapters have proposed an analysis of the ethical nature of engineering and have shown how the analysis applies to engineering for peace, engineering for health and engineering for development. However, some academic observers, including a few engineers, have argued that there are a number of reasons why engineers cannot, in practice, truly accept and express ethical responsibility. In this chapter, these arguments will be investigated using an example given by Alasdair MacIntyre and by considering and developing an analysis presented by Michael Davis. It will be concluded that the objections are flawed and that engineers really do have opportunities to accept and express ethical responsibility.

Nevertheless, engineers are subjected to pressures in their professional life that can make this ethical task difficult. It is therefore of benefit if engineers participate in what was described in Chap. 1 as a base community—a community in which ethical discourse is promoted and in which generous ethical action is stimulated. The present chapter will consider two examples of such base communities: trade unions and faith communities. Specific cases will be described to show that such base communities can greatly enhance innovation in the acceptance and expression of ethical responsibility in engineering.

6.2 The Case of J

In an article that is very relevant to professional ethics, Alasdair MacIntyre imagined the case of J (somebody, *jemand*) who 'used to inhabit a social order, or rather an area within a social order, where socially approved roles were unusually well defined. Responsibilities were allocated to each role and each sphere of role-structured activity was clearly demarcated…The key moral concepts that education had inculcated into J were concepts of duty and responsibility' [1]. In his

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work, J was responsible for the scheduling and efficient operation of trains. At the start of his career, J had been interested in what these trains carried, whether people or various cargoes. However, he had been instructed by his superiors 'to take *no* interest in such questions, but to attend *only* to what belonged to his role, so as not to be irresponsibly distracted'. He followed these instructions even through a later period when the freight was weapons and passengers were Jews on their way to extermination camps. When J was subsequently questioned about this, he said sincerely: 'I did not know. It was not for someone in my position to know. I did my duty. I did not fail in my responsibilities. You cannot charge me with moral failure' [2]. The question which MacIntyre asks and explores is, 'Was J's defence adequate?'.

6.3 Arguments Against the Personal Responsibility of Engineers

The case of J as presented by MacIntyre appears at first to be rather extreme, and it is in some ways a deliberate parody of certain philosophical views. However, it echoes some aspects of professional activities that are relevant to engineering and analogies to J's defence have been discussed in the context of engineering ethics. Michael Davis has described these as 'arguments against holding engineers responsible for what they do' [3]. Davis identifies seven such arguments, and they will be considered here though with a different emphasis and with a somewhat different analysis to that which he gives. These will be considered in two groups, the first group consisting of what might be termed generic arguments and the second group being particularly related to the way in which the work of engineers takes place in institutions.

One frequently cited generic argument is that the role of engineers is to produce technology and that technology is in itself *ethically neutral*. From this point of view, ethical issues only arise when technology is used and engineers cannot be held responsible for what is done with their work. This view is based on a serious misunderstanding of the nature of engineering. As has been described in Chap. 2, the purposive social ends of engineering are the enhancement of welfare, health and safety, with an overall goal that may be described as *the promotion of the flourishing of persons in communities though contribution to material wellbeing*. Engineers working to fulfil this goal will be very concerned about the effects of their work. Technological artefacts are not the goal of engineering but rather external goods, contingent products. Davis expresses a similar view very succinctly, 'An engineer who produces a product that, however clever, fails to benefit humanity has failed—as an engineer' [4]. There are, of course, issues about engineered artefacts being used in ways other than those intended or envisaged. However, good engineering seeks to design products so as to limit unintentionally harmful or wilfully malicious use. Furthermore, this argument of the ethical neutrality of technology also misunderstands an aspect of the practical nature of engineering activities. Engineers are certainly concerned with the design and manufacture of technology, but such technology also often requires continuing engineering input in its use, allowing undesirable outcomes to be corrected. Additionally, wilfully malicious use of sophisticated modern technology will typically require input of engineering knowledge and skills for the modification of a beneficial artefact, input which ethically aware engineers would not provide.

A second generic argument is the issue of *many causes*. This is in part a deep philosophical problem as to how a first event (cause) is related to a second event (effect), a problem that has generated debate since at least the time of Aristotle. In some contrast to this problem is a human tendency to wish to identify a proximate cause of an event as being *the* cause even though the entire situation surrounding the effect really requires consideration. However, on the contrary, in the context of engineering activities, the issue of many causes is characteristically concerned with elucidating the complex origin of certain events. For example, Davis notes that an accident involving an engineered process might involve operator error (failure to follow instructions), organisational failure (inadequate training, supervision or quality assurance) or design flaw (mechanical or software). Indeed, as engineers usually take great care to design processes that operate safely, serious accidents typically occur when two or more such factors arise and combine in a very unexpected way. Furthermore, when such an incident does take place, it is inherent in the practice of engineering, indeed essential for the maintenance and systematic extension of the goals, internal goods and virtues of the practice, that the circumstances are comprehensively investigated. That is, the approach of engineers to the issue of many causes is pragmatic, and particularly concerned with ensuring that such an incident does not occur again.

A third generic argument concerns the issue of *replaceability*. Davis notes a typical form of this argument, 'If I don't do this, someone else will, and since it makes no difference whether I do it or not, there's nothing wrong with me doing it' [5]. In engineering contexts, this argument is often accompanied by there being some significant tangible external goods, usually wealth, accruing to the 'I' carrying out the action. The argument may be made at all levels of engineering activities. For example, a young, inexperienced engineer might use the argument in accepting a first job in some dubious enterprise. The argument is even more pernicious when used by experienced engineers with positions of high responsibility, seeking for example to gain a contract to provide weapons or supporting military equipment to a country known to have an external belligerent intent or a determination to violently suppress internal political engagement. There are several flaws in the argument. There can never be certain knowledge that the act would be carried out by another. Indeed, not carrying out the act might discourage others from doing so. Furthermore, engagement in dubious activities may give a short-term gain in external goods, but the consequent loss of reputation may well give a long-term loss. However, the greatest loss arises from the certainty that it *does* make a difference whether 'I' do it or not. As John Finnis concisely expresses, 'Thus one's free choices, whether of particular acts, or of complex projects, or of overarching commitments, constitute one the sort of person—indeed, *the* person—one has made oneself' [6]. The ethical coherence of an engineer's life can be put at risk at least as much as can the life of a torturer.

The second group of arguments is particularly related to the way in which the work of engineers takes place within certain types of institutions. One of the most frequently cited of these is termed by Davis the argument from *institutional constraint*. This is based on the observation that most engineers work in large organisations, either commercial or governmental, and then proceeds on the assumption that their capacity to act is severely constrained by the corporate pressures inherent in such organisations. Some caution concerning these basic assumptions is warranted. It is certainly the case that many engineers work in large organisations, but there are also many that work in medium-sized and small-sized enterprises. Indeed, there are significant numbers who create their own entrepreneurial businesses. Also, there are differences between the branches of engineering. For example, in some branches, such as aerospace engineering, there are a few but very large employers, whereas chemical engineers increasingly work in small businesses concerned with environmental protection or food processing. Institutional constraints are less rigid in smaller organisations. Furthermore, engineers may work at all levels within large organisations and those towards the top may have considerable freedom of action. Additionally, even minor actions at lower levels in large organisations, say an ingenious improvement to a small feature of a major product, can have considerable effects on human flourishing. Importantly, engineers are employed for the range of knowledge and skills which they possess, so that an employer that unduly limits their freedom to make expert decisions is acting against its own best interests. Finally, engineers freely choose to work for specific organisations and are free to leave if they find the constraints unacceptable. Conversely, the most important decision that many engineers make is the choice of their employer, for this may have a profound influence on their ability to further the ethical practice of engineering.

A second argument concerning work taking place in institutions is the problem of *many hands*. Davis ascribes this term to Dennis Thompson who first applied it to government, 'Because many different officials contribute in many different ways to decisions and policies of government, it is difficult even in principle to identify who is morally responsible for political outcomes' [7]. Davis notes that this is an epistemic problem for those outside the activity concerned. Those actually involved in the decision making processes will in most cases know clearly what their own contribution has been. It should additionally be noted that in engineering organisations the formal procedures for record keeping and the requirement to formally authorise activities provide good documentary evidence for where responsibility lies. Furthermore, such record keeping and authorisation are the acts of individuals.

A third argument concerned with institutions is that of *individual ignorance*. J claimed such ignorance, 'I did not know. It was not for someone in my position to know', and we will return to MacIntyre's analysis in the next section. However, the argument specifically with regard to engineering is that engineering projects are often very large and that it is difficult for any individual engineer, and especially one who occupies a lowly position in the hierarchy, to have knowledge of the whole. Indeed, some organisations such as weapons manufacturers may organise their employees in such a way as to make it difficult for any individual to appreciate the real applications of their work. Nevertheless, it is surely bizarre that highly educated professionals of a practice committed to the promotion of human flourishing should not seek to discover the real scope of projects on which they work. Moreover, seeking such knowledge is essential for the maintenance of the engineering virtues of honesty and integrity, and respect for life, law and the public good. As Philippa Foot writes of voluntary ignorance, 'an agent's ignorance may be imputed to his will if, through negligence, he has not taken the trouble to find out facts that he could, and should, have known…The omission may be culpable on account of some special position of responsibility held by the agent' [8]. In the case of professional engineers, such voluntary ignorance would certainly be culpable ignorance.

The fourth argument concerned with institutions is that of *individual helplessness*. Here, the argument is that in most cases an individual engineer can do nothing for they always have to act in cooperation with other engineers. However, this is not an argument against the personal responsibility of engineers but rather a description of how engineers typically are best able to express that responsibility. Here, it is worth quoting again the opening paragraph of the Royal Academy of Engineering's *Statement of Ethical Principles*:

> Professional Engineers work to enhance the welfare, health and safety of all whilst paying due regard to the environment and the sustainability of resources. They have made personal and professional commitments to enhance the wellbeing of society through the exploitation of knowledge and the management of creative teams [9].

It is through working together, by collaborative management of creative teams, that engineers can best find expression of responsibility and the systematic extension of their practice.

6.4 The Acceptance of Ethical Responsibility

J's claim was essentially that in fulfiling the role assigned to him, he had also fulfiled his ethical responsibilities. MacIntyre concludes that in making this claim, J has misunderstood the nature of ethical agency, and he develops his analysis by investigating what it is to understand oneself as an ethical agent. He identifies three key features for such agency: (i) understanding oneself as someone with an identity that transcends specific roles; (ii) understanding oneself as capable of practical and rational judgement; (iii) participation in a social setting that promotes critical ethical discourse.

During a lifetime, an individual may take on many roles that change with time and circumstances. However, we all have an experience of an identity that transcends these roles, an experience of personhood: we can say ‘It’s me here!’. This subjective character is important to all of us: there is definitely something it *feels* like to be a person. As a minimum, being a person involves a ‘point of view’ that can help give an account of rationality, free choice, decision making, reasons for action, responsibility and planning, all as parts of a unified and continuous experience of consciousness [10]. We experience this continuity even as our lives change with time. Furthermore, there is a narrative dimension to our lives of which we have an important part in authorship. We therefore seek continuity and coherence in our actions in the various aspects of our life. These features of being a person have, since antiquity, found expression in the view of ethics as having an aim of leading an accomplished *life*.

MacIntyre’s J seems to have forgotten that he was a person. He seems not to have asked himself a question of the type, ‘How is it best for a person in my circumstances to live?’. He has rather considered his closely defined professional role in isolation. In MacIntyre’s analysis, this compartmentalisation of J’s life is not simply an error of omission but an active refusal on J’s part. He has arbitrarily closed his mind to certain types of knowledge and possibilities of action. Indeed, it could be said that he has failed as a person, as a human being, for he has sought to fulfil a closely specified role rather than to lead an accomplished life.

If J had enjoyed the benefit of Davis’s knowledge of the professional ethics literature, he could have suggested a more comprehensive list of why he had not failed his responsibilities. However, this would not have much helped his defence, especially if he was an engineer. The comments on the seven arguments against the personal responsibility of engineers have shown that each of the arguments is flawed in a serious manner. This was also Davis’s conclusion.

An important feature of why J’s defence is weak, and of why the seven arguments are flawed, is that just as it is possible to follow J and avoid responsibility, it is also possible to make a decision to seek and to accept responsibility. However, to do so the individual must have confidence that he or she is capable of making practical and rational judgements. We know nothing of how J might have acquired such confidence. However, we do know that professional engineers have received at least four years of university level education followed by a further 4-year period of training and work experience. An important aspect of such education and training aims to give them confidence in making practical and rational judgements, at least regarding technical decisions. This is expressed in the engineering virtues of accuracy and rigour: ‘Professional Engineers have a duty to ensure that they acquire and use wisely and faithfully the knowledge that is relevant to the engineering skills needed in their work in the service of others’ [9]. Important initiatives are also taking place to ensure that all university engineering courses integrate the teaching of ethics with the technical content of engineering, so this confidence in practical and rational judgement should also increasingly extend in future to ethical matters.

There is a reason why J might have had a weak sense of personhood and a weak sense of his ability to make practical and rational judgements. He lived in a society in which the importance of dutiful fulfilment of role was greatly emphasised and in which personal initiative was strongly discouraged. What he seems to have lacked is participation in a social setting that could have given him a sense of the value of his personhood that was independent of his professional role, that could have challenged the compartmentalisation of his life, and that could have promoted compassionate ethical discourse and an attitude of interpersonal accountability. MacIntyre's examples of such social settings are, 'the everyday life of certain kinds of family and household, of certain kinds of workplace, of certain kinds of school and church, and of a variety of local community' [11]. All of these can provide practical experience of living together in ways that are sensitive to the personhood of others. Such social settings provide a communal base from which the demands of external roles can be viewed.

Most engineers are fortunate to live in societies that are less regimented than that of J. They will hence have the required sense of personhood and confidence in practical and rational judgement which are essential conditions for the acceptance of ethical responsibility. They may also have the benefit of participation in the types of social settings that MacIntyre identifies. However, the beneficial contribution of participation in such settings has been somewhat overlooked in discussion of engineering ethics. Hence, the following sections will describe some contributions of two important types of social settings in which ethical discourse that is particularly relevant to the practice of engineering is promoted: trade unions and faith communities.

6.5 Trade Unions: The Lucas Plan

Trade unions are one of the most important modern examples of how individuals have grouped together and collaborated on activities for the common good. Trade unions have characteristically been concerned with the negotiation of fair remuneration and the development of safe working conditions for their members. They have also made important contributions to the support of members during periods of unemployment or ill health, and in old age. In many countries, these benefits were the forerunners for the current state provision. Trade unions have also made important contributions to the analysis of business strategies. This section describes the contribution of trade unions to the formulation of a business plan for Lucas Aerospace, a major UK based designer and manufacturer of aerospace components and systems for military purposes, in the 1970s. Development of the plan involved a close collaboration of engineers and technicians, all of whom were union members. Union membership provided a social space for the discussion and development of innovative approaches to ethical business priorities and ethical working practices, in particular the development of socially beneficial products.

An important precursor of the plan arose due to a visit of union members to a centre for children suffering from spina bifida. They were horrified to find that the only way that some of the children could move was by dragging themselves on the floor with their hands and arms. This led to the development of a prototype vehicle, a 'hobcart', specifically designed for one three-year-old child, David Smith, who was almost totally immobilised. It is worth quoting a description of this work that illustrates in a remarkable way a convergence of the goal, external goods and internal goods of engineering described in Chap. 2:

> Mike Parry Evans, its designer, said that it was one of the most enriching experiences of his life when he delivered the hobcart to the child and saw the pleasure on the child's face. It meant more to him, he said, than all the design activity he had been involved in up till then. For the first time in his career, he saw the person who was going to benefit from the product he had designed, and he was intimately in contact with a social human problem. He needed to make a clay mould of the child's back so that the seat would support it properly. He was working in a multidisciplinary team together with a medical doctor, a physiotherapist and a health visitor. This illustrates very graphically that aerospace technologists are not only interested in complex esoteric technical problems. It can be far more enriching for them if they are allowed to relate their technology to real human and social problems [12].[1]

Lucas Aerospace declined to manufacture the hobcart, despite considerable international demand, as it was incompatible with their product range. It was subsequently manufactured elsewhere.

Staff at Lucas Aerospace were becoming increasingly concerned at the enormous gap between what engineering could provide for society and what it actually did provide. For example, even in a technologically sophisticated country like the UK, people were still dying of cold during the winter (and still are). Again, although it was possible to guide a missile system to another country with an accuracy of a few metres, blind and otherwise disabled people had great difficulty finding their way around built environments. The staff were also concerned that their scope to make maximum use of their knowledge and skills was decreasing as their work was increasingly becoming defined in terms of narrow roles. At the same time, they faced job losses due to reorganisation of the aerospace industry and government policies of 'structural unemployment'. It seemed absurd that they had skills, knowledge and facilities that could provide society with urgently needed services yet the market economy seemed incapable of linking the two. They therefore developed the idea of a campaign that would enable them to work on socially useful products.

A steering group sent a letter to 180 leading institutions and experts giving a detailed account of the facilities and skills at Lucas Aerospace and asking a simple question, 'What could a work force with these facilities be making that would be in the interests of the community at large?'. Only four replies were received, though these were all useful. In the words of one of the leading figures of the campaign, 'We then did what we should have done in the first place. We asked our own members what they should be making' [13]. The members were asked to consider the question as both producers and consumers so that their work could be relevant to the communities in which they lived. They were asked to consider the use value as well as the exchange value of potential products. Within four weeks, 150 ideas

[1] I thank Rob Baker for drawing my attention to this work.

of products had been suggested. These were refined and grouped into six major product ranges that were eventually described in six volumes, each of about 200 pages. These descriptions included technical details, engineering drawings and economic calculations. A mixture of products was included: some that could be manufactured in the short-term and some requiring long-term development; some suitable for developed countries and some suitable for developing countries; some which would be immediately profitable in a market economy and some of high social usefulness that would not necessarily be immediately profitable. Hence, the plan proposed a gradual diversification of Lucas Aerospace's business.

It is still astonishing to note the strikingly prescient originality of many of the ideas that the Lucas Aerospace staff proposed when they were encouraged to make full use of their knowledge, skills, imagination and social awareness. Though these suggestions were made almost forty years ago, many would still be considered leading-edge technology. These included [14, 15]: *medical equipment*—portable kidney dialysis equipment, a portable life support system for ambulances, artificial limb control systems and sight aids for the blind; *energy technology*—solar and wind energy technology, innovative heat pumps and fuel cells, multi-fuel power generators for developing countries; *transport*—hybrid petrol/electric power packs for cars (remarkably like the latest available now), a hybrid road-rail vehicle; *oceanics*—a range of ideas relating to exploration for and extraction of oil and natural gas, the collection of mineral bearing nodules and submarine agriculture. It is important to emphasise that these suggestions were made on the basis of a high level of knowledge and skills. For example, the ideas for sight aids for the blind arose from expertise in radar technology, wind energy proposals arose from expertise in aerodynamics and hybrid vehicle proposals arose from in-depth understanding of electric motors. However, the goal of producing socially useful products was also a crucial factor, 'a desire to meet real social needs is a vitally important stimulus to good quality and creative design, and is a qualitative element of design which cannot be treated in a mathematical way as the quantitative elements can' [16].

The intentions of the engineers and technical staff at Lucas Aerospace were entirely constructive, seeking to contribute to the long-term flourishing of the company and society. However, the management of the company rejected the proposed plan. The key issue seems not to have been the viability of the products from an engineering or economic viewpoint, but the question of who managed the company. The plan was proposed at a time of very turbulent industrial relations in the UK and management in the aerospace industries was considered to be particularly autocratic. A leading engineering publication noted the folly of this rejection, 'with the total rejection of the Corporate Plan prepared by shop stewards at Lucas Aerospace factories, the firm's management may have scuttled potentially profitable ideas as well as a peaceful future' [17]. With the benefit of hindsight, even from a purely economic viewpoint, this comment seems to be a huge understatement: following the best aspects of the plan could have made Lucas Aerospace an enormously innovative and profitable company. The plan's products would have provided a great opportunity for an enterprising company with a sensitivity for future markets, long-term stability and social awareness. However, the company lacked these characteristics and chose to rely instead on more predictable cost-plus military contracts [18]. Many of the proposed products have since been developed, or are under development, elsewhere.

The Lucas Plan arose from a social setting, the trade union movement, which promoted imaginative ethical discourse. The events at Lucas Aerospace have two important lessons for the acceptance of ethical responsibility by engineers:

1. That when engineers and technical staff have the motivation and opportunity to think creatively about their work, they are able to make highly innovative proposals that show great prospects for sustainable employment, sustainable profitability and socially beneficial application.
2. That such promise can only be fulfiled in work environments that value the total contribution that each employee can make. Work environments that constrain employees to the simple fulfilment of a role fail to benefit from the available creativity: institutional constraints work against the best interests of the organisation.

For these reasons, the next section looks at institutional arrangements that are better equipped to promote both technical excellence and ethical engagement.

6.6 Faith Communities: Saint Benedict

Perhaps the most familiar of social settings that can promote creative and profound ethical discourse are faith communities. Faith communities are in the present context understood to include not only those associated with specific religions but also groupings such as humanist associations which provide social settings for ethical reflection and ethical engagement [19]. In contemporary Western societies, such communities are one of the few types of social space where individuals of a great variety of social backgrounds, and of all ages, can meet on an equal basis. They thus serve as important resources for ethical awareness of the needs and aspirations of others. They are also one of the few remaining contemporary social spaces in which individuals are valued as unique and irreplaceable persons, independently of the dominant consequentialist assessments which are elsewhere pervasive. To show how faith communities can benefit engineering ethics, this section will consider the practices of Benedictine communities that follow the *Rule of Saint Benedict* [20].

The *Rule of Saint Benedict* was originally written to guide the life of monastic communities in the sixth century. Given this origin, consideration of the *Rule* in a discussion of engineering ethics may initially seem anomalous. However, the *Rule* has long been seen as valuable in providing guidance for an active life in a much wider context. For example, in the Middle Ages, it was used as a textbook for the education of the sons of nobility and as a handbook for wise rule [21].

More recently, it has been proposed that the *Rule* can provide a foundation for the creation of an ethically and spiritually credible civilisation in Europe [22]. Among the important factors leading to this latter suggestion are that the *Rule* provides a rich basis for the creation of community and in particular is concerned with how attention to material and practical matters can create the conditions for ethical and spiritual flourishing.

A further indication that consideration of the *Rule* may help the enrichment of engineering ethics is the high evaluation that its approach has been given by some leading modern exponents of philosophical and theological ethics. For example, MacIntyre's seminal appraisal of moral philosophy in *After Virtue* was much concerned with the role of communities in sustaining ethical life. This work ended with the words 'We are waiting not for Godot, but for another—doubtless very different—St. Benedict' [23]. Again, Banner's recent, succinct account of the development of Christian ethics begins with a chapter entitled 'Benedict and the Practice of the Christian Life', that describes the *Rule* as 'what can plausibly be seen as Christianity's paradigmatic framing and answering of the question of ethics' [24].

The interest in Benedict's approaches shown by experts in business management provides an additional pointer that study of the *Rule* may be beneficial in the development of engineering ethics, for there is a close connection between engineering and business. The *Rule* is much concerned with practical work, and monasteries following it have been expected to be self-sufficient. Indeed, such monasteries have operated with commercial success for over 1,300 years, suggesting that they may have much to teach other businesses. Detailed study of commercially successful businesses employing mostly lay people in a manner inspired by the *Rule* has confirmed the linkage of quality of work environment and quality of output achieved through avoidance of the instrumentalisation of either work or people. Indeed, there is much interest in applying the outlook of the *Rule* to businesses with no religious connection, particularly its emphasis on prioritising the person (employee) rather than the task to be carried out [25].

Thus, there are a number of indications that the *Rule* may profitably be studied in the present context: its historically widespread use outside monastic communities, its significance to philosophical ethics, its paradigmatic place in Christian ethics and its application in business management. Moreover, there are further indications that the *Rule* may have particular relevance for engineers, especially its pragmatic approach to practical work and the life of persons in a community. Both the *Rule* and engineers are practical rather than theoretical, realist rather than idealist, and prioritise specific, achievable actions rather than unattainable, ethereal visions. Indeed, it is no coincidence that monasteries following the *Rule* were pioneers of early engineering, including the construction of complex yet functional buildings, harnessing hydropower for milling, wood cutting and metal working, drinking water management, sewage disposal, mining and iron smelting [26].

It was noted in Chap. 1 that the Royal Academy of Engineering's *Statement of Ethical Principles*, in common with other modern professional ethical codes, is concerned with *what* should be done. This is also a concern of the *Rule*, but the

Rule additionally considers *how* and *why* desirable actions should be accomplished. *What* should be done may be summarised as ‘faith and the performance of good works’ or ‘love the Lord God with your whole heart, your whole soul and all your strength, and your neighbour as yourself’ [27]. These are Christian formulations of attitudes and actions that are held in common by most faiths, though some (such as Buddhists and humanists) may not make explicit reference to ‘God’. In common with almost all faith communities, the *Rule* gives priority to the sick and otherwise vulnerable, stressing the importance of the community formed through persons living together, whilst always respecting the dignity of each person. Concerning *how* desirable actions may be accomplished, the *Rule* gives priority to establishing a *rhythm* for each day structured around worship and prayer, labour and study. That is, the *Rule* describes an integrated way of life in which prayerful worship, labour and study are intimately connected. The *Rule*’s reasons for why life should be lived in these ways are based on New Testament ethical teaching, especially that concerning care for the sick and poor. However, the *Rule* does not seek to establish a rigid set of instructions based on this source, but rather aims to provide a framework for a synthesis of action and contemplation, interiority and engagement, relationship to God and standing within the world.

Additionally, the *Rule* provides insights on a number of specific matters that are of concern to engineering ethics. For instance, although practical work is of importance in the *Rule*, it is always considered within the wider context of the life of the person and the community. Indeed, prayerful worship and work are seen as a unity. This gives dignity to the activities of the worker: work is more than a means of production. There results a form of economics that recognises the role of material needs but only in the context of profound ethical and spiritual values. This has specific consequences, for example, regarding the sale of goods produced by artisans in the monastery: ‘The evil of avarice must have no part in establishing prices’ [28]. The monks themselves had no personal possessions but rather received a few necessary goods according to their needs.

The *Rule* also gives insights into a distinctive type of obedience, or in more modern terms organisation and hierarchy. This is particularly evident in a type of authority that has been described as ‘not representative in the modern sense, but at least systematically attentive to the diversity of character and experience within the community’ [22]. Thus, considerable power is vested in the head of the monastery, the abbot, but this is balanced by the requirement for the abbot to consult extensively, showing care and concern for each person in the community and, above all, discernment. All take part in the consultation process, even the youngest members of the community, for the knowledge and ability of all is valued.

A further very pertinent insight of the *Rule*, implicit rather than explicit, is what may be termed ‘Benedictine Peace’. Importantly, Benedictine Peace does not involve a grand programme of action, but rather concerns each person seeking to create peace in his or her immediate community, a culture of peace arising from personal inner peace: ‘The Benedictine ideal of the human being is not that of one who achieves and accomplishes things, not a person with an unusual religious gift, not a great ascetic, but the wise and mature person who knows how to bring people together, who creates around herself or himself an atmosphere of peace and mutual understanding' [29].

Consideration of the *Rule* suggests a number of ways in which the taking of ethical responsibility by engineers may be promoted and enriched. Maintenance of high professional ethical aspirations requires a level of commitment that it is not easy to attain and sustain. However, professional activities are only one component of a person's life, and a clear lesson of the *Rule* is the importance of seeking coherence in work and faith. Such coherence parallels the existing recognition that the coherence of professional and personal ethical values is an important component in the promotion of high professional standards [30]. The *Rule* emphasises the importance of a rhythm of work and prayerful worship, detailing a demanding schedule throughout the day and night. Such a rigour is unattainable outside of monastic life. Nevertheless, simply developing a modest rhythm of work and reflection has the potential for providing time for ethical engagement. Professional engineering activities can otherwise become overly intense—the time pressures of engineering work, especially in large organisations, can greatly limit the opportunities for necessary ethical assessment. Furthermore, encouraging the adoption of such a rhythm may be useful in helping engineers meet the difficult challenge of achieving a balance of personal and professional ethical commitments. Such a rhythm can also have benefits for the purely technical aspects of engineering work. Thus, the electrical engineer Godfrey Hounsfield, who received the 1979 Nobel Prize for medicine for his part in developing X-ray computed tomography, has observed on his habit of taking walks, 'It is a time when things come to one, I find. The seeds of what happened came on a ramble' [31].

Consideration of the *Rule* can also lead to richer interpretations of the engineering virtues or principles described in Chap. 2. For instance, the economic practices described in the *Rule* go beyond *honesty and integrity* and suggest the possibility of trading practices that, while financially sound, also seek to instantiate ethical and spiritual values. Similarly, engineering businesses need not always seek solely the maximisation of profits. Again, the *Rule* goes beyond *respect for life, law and the public good* in its particular identification of the prioritisation of care for the sick and poor. For modern engineering, this might be expressed by particular concern with the amelioration of infrastructural poverty wherever it occurs. Furthermore, the *Rule's* emphasis on systematic attentiveness to the needs of others is very relevant to modern engineers' *responsible leadership, listening and informing*. They have at their disposal a range of knowledge, skills, techniques and technologies of unique potential, the wise use of which requires discernment analogous to that required of a Benedictine abbot. Crucially, engineers can use their responsible leadership in the pursuit of real peace, such as the *Rule* implies. As described in Chap. 3, most of the world's violent conflict is carried out using engineered artefacts, but engineers have the practical skills to remove many of the root causes of conflict and hence promote sustainable peace. Such enriched interpretation of the fundamental virtues or principles can provide valuable guidance for meeting the very important challenge to engineers of matching their great technical innovation with a corresponding innovation in the acceptance and expression of ethical responsibility.

Consideration of the *Rule* can stimulate ethical aspirations by providing the foundation for the identified need for a compassionate and generous ethical culture within the engineering profession [32, 33]. In keeping with the spirit of the *Rule*, such a culture would recognise the vital need for each engineer to accept responsibility for undertaking those specific actions that can contribute to enhancing the flourishing of all. Engineers promote human flourishing through manipulation of the material world, and a key lesson of the *Rule* is that in doing so they need particularly to be sensitive to the ways in which personal relationships, interactions with the natural environment and also spiritual needs are components of such flourishing and are affected by such manipulation.

The range of businesses run by Benedictine communities currently includes publishing, data management, metallurgical processing for the automobile industry, dairies, bakeries and health foods. Many are businesses that have multi-million Euro turnovers and so are of a scale that requires the employment of lay people. An important question then arises: can these work environments themselves provide a social setting in which both technical excellence and ethical engagement are promoted? A detailed study of one such business has concluded that following the guidance of the *Rule* did result in a more humane organisation that was at the same time technically excellent and commercially very successful [34]. The business studied was a brewery, an activity for which Benedictines are famous and also an activity that is an important aspect of biochemical engineering. Except for a monk with overall responsibility, all of the staff were lay people, 'not all of them Catholics or even Christians; there were several atheists, a Marxist and a freemason among the employees' [35].

This brewery was succeeding in a market that was conventionally highly competitive, very dependent on marketing and very changeable. However, there were great contrasts between the business characteristics of this brewery and conventional corporate practice (*CCP*). Some of these may be summarised in the following way:

Personnel environment

Rule: An intentional community with long-term commitment of employees. Employment to maximise the contribution of the person. An attitude of cooperation for mutual benefit. Care of families and retired employees.
CCP: Employees working at a 'cynical distance' with only superficial identification with the organisation. Employment to fulfil a specific role. An attitude of competition. High staff turnover.

Management style

Rule: Emphasis on subsidiarity, personal responsibility and personal discernment. Holistic development of each employee.

CCP: Top-down delegation requiring following of orders. Channelling, exploitation or selective development of employees.

Meaning of work

Rule: Value based—intrinsic rewards are very important. Material survival of persons and community, with provision of personal life balance.
CCP: Commercially based. Material survival of self and family.

Financial reward of employees

Rule: ‘To each according to needs’. Lay people well paid but without dramatic increments.
CCP: Large differences and highly competitive.

Interaction with outside business environment

Rule: Clear distinction. Scepticism to practices such as rapid business expansion and continual maximisation of profit.
CCP: Permissive following of current practices.

The conclusions of the authors of the study include two observations that are very relevant to engineering:

1. Benedictines successfully conduct businesses with these characteristics across a wide range of industries, and these businesses have as an important common factor the provision of products or services where quality is more important than price. They all show that quality of output, quality of work environment and quality of staff are closely linked. They show that ethically sensitive work practices can be highly successful in a manner that can be sustained over long periods of time, provided that there are customers who appreciate and desire quality.
2. The key *Rule* management principle of subsidiarity requires a highly qualified workforce, educated as ‘whole persons’ with a clear appreciation of the wider context of their work and with a commitment to take responsibility. That is, it requires staff who are committed to both quality of work done and quality of life.

This chapter has shown that engineers really do have opportunities to accept and express ethical responsibility in their professional working lives. Participation in a base community, such as a trade union or faith community, in which ethical discourse is promoted and in which generous ethical action is stimulated, can greatly enhance innovation in the acceptance and expression of such ethical responsibility. Of course, such participation in the case of faith communities would usually be quite separate from the professional engineering activities. Furthermore, businesses that adopt practices in which both technical excellence and ethical engagement are promoted, such as those guided by the *Rule of St. Benedict*, can sustain high levels of commercial success. Despite such demonstrable benefits, ethically engaged engineers may still need further arguments to convince decision makers, such as business leaders and politicians, of the benefits of using engineering to promote the flourishing of persons and communities. The next chapter will consider two such additional approaches: human rights and engineering power.[2]

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Chapter 7
Convincing Others: Engineering for Human Rights and Engineering Power

7.1 Introduction

Engineers who wish to promote imaginative innovation in the acceptance and expression of ethical responsibility in their profession need to convince others, especially their fellow engineers and decision makers, of the validity and practicality of their ethical vision. The preceding chapter showed how participation in base communities, such as trade unions and faith communities, can promote innovative ethical discourse and generous ethical action. Such participation might be termed a bottom-up approach.

In contrast, this chapter will consider what might be termed top-down approaches. The first will be based on the broad international consensus on the validity and value of human rights. In particular, the recent international application of human rights approaches to business activities provides an important means of expressing the ethical challenges and opportunities for engineers in an universally understood language. Such a human rights approach can be readily understood by business managers and politicians. It has the additional advantage of legal backing. The second approach to be described will aim more specifically to find a means of convincing Western politicians of the scope for engineering to contribute to human flourishing. This is a difficult task as most leading Western politicians have a very poor knowledge of the nature of engineering. Based on the writings of a leading ethically engaged twentieth century politician, Aneurin Bevan, and a leading political theorist, Joseph S. Nye, it will be suggested that the best way to communicate with politicians is to use the language of political power. Extending Nye's concepts of soft power, smart power and relational power it will be proposed that engineers should engage politicians through discussion of *engineering power*, the ability to attain preferred outcomes through the peaceful use of engineering capabilities.

W. R. Bowen, *Engineering Ethics*, DOI: 10.1007/978-3-319-04096-7_7,

7.2 The International Consensus on Human Rights

The development of a broad international consensus about the importance of human rights is one of the outstanding achievements of the twentieth century. The concept of human rights may be described as:

> There is something about each and every human being, simply as a human being, such that certain choices should be made and certain choices rejected; in particular, certain things ought not to be done to any human being and certain other things ought to be done for every human being [1].

The international consensus about this concept was first and most prominently demonstrated in 1948 through the United Nations' *Universal Declaration of Human Rights* (UDHR).[1] This recognises that respect for the inherent dignity, and consequently certain equal and inalienable rights, of all human beings is the foundation of freedom, justice and peace in the world. These rights are described in the 30 articles of the *Declaration*. The preamble to the *Declaration* concludes with:

> The General Assembly proclaims this Universal Declaration of Human Rights as a common standard of achievement for all peoples and all nations, to the end that every individual and every organ of society, keeping this Declaration constantly in mind, shall strive by teaching and education to promote respect for these rights and freedoms and by progressive measures, national and international, to secure their universal and effective recognition and observance, both among the peoples of Member States themselves and among the peoples of territories under their jurisdiction.

This is a highly aspirational statement, for although the declaration was adopted by representatives of states it is declared to be a common standard for which 'every individual and organ of society' shall strive. Hence, the first article specifies both rights and obligations:

> *Article 1*
>
> All human beings are born free and equal in dignity and rights. They are endowed with reason and conscience and should act towards one another in a spirit of brotherhood.

In the present context it is also pertinent to note Article 27:

> *Article 27*
>
> 1. Everyone has the right freely to participate in the cultural life of the community, to enjoy the arts and to share in scientific advancement and its benefits.
> 2. Everyone has the right to the protection of the moral and material interests resulting from any scientific, literary or artistic production of which he is the author.

[1] The texts of the UDHR and other components of the *International Bill of Human Rights* are available at [2].

Like most international documents, the *Declaration* contains no specific reference to engineering, but here 'science' is usually understood to include both engineering and medicine.

The Declaration is not legally binding, but it has been developed in a binding way through various international, regional and national legal instruments. At the international level, two of the most important are the *International Covenant on Economic, Social and Cultural Rights (ICESCR)* and the *International Covenant on Civil and Political Rights (ICCPR)*. These were adopted by the UN General Assembly in 1966 and came into force in 1976. Now 160 states are party to the ICESCR and 167 are party to the ICCPR. The Declaration and these two Covenants are jointly referred to as the *International Bill of Human Rights*. The scope of these two Covenants is as follows:

International Covenant on Economic, Social and Cultural Rights

Article 1	Right of self-determination
Articles 2–5	Overarching principles
Article 6	Right to work
Article 7	Right to enjoy just and favourable conditions of work
Article 8	Right to form and join trade unions, and the right to strike
Article 9	Right to social security, including social insurance
Article 10	Right to a family life
Article 11	Right to an adequate standard of living
Article 12	Right to health
Articles 13 and 14	Right to education
Article 15	Rights to take part in cultural life, to benefit from scientific progress, and of the material and moral rights of authors and inventors

International Covenant on Civil and Political Rights

Article 1	Right of self-determination
Articles 2–5	Overarching principles
Article 6	Right to life
Article 7	Right not to be subjected to torture, cruel, inhuman and/or degrading treatment or punishment
Article 8	Right not to be subjected to slavery, servitude or forced labour
Article 9	Rights to liberty and security of the person
Article 10	Right of detained persons to humane treatment
Article 11	Right not to be subjected to imprisonment for inability to fulfil a contract
Article 12	Right to freedom of movement
Articles 13	Right of aliens to due process when facing expulsion
Article 14	Right to a fair trial
Article 15	Right to be free from retroactive criminal law
Article 16	Right to recognition as a person before the law
Article 17	Right to privacy
Article 18	Rights to freedom of thought, conscience and religion

Article 19	Rights to freedom of opinion and expression
Article 20	Rights to freedom from war propaganda, and freedom from incitement to racial, religious or national hatred
Article 21	Right to freedom of assembly
Article 22	Right to freedom of association
Article 23	Rights of protection of the family and the right to marry
Article 24	Rights of protection for the child
Article 25	Right to participate in public life
Article 26	Right to equality before the law, equal protection of the law and rights of non-discrimination
Article 27	Rights of minorities

Engineering can affect the fulfilment of all of these rights, and some of the ways in which this can occur will be discussed later. However, here it is pertinent to draw attention to two of the articles of the ICESCR that are most obviously relevant to engineering:

Article 11

1. The States Parties to the present Covenant recognize the right of everyone to an adequate standard of living for himself and his family, including adequate food, clothing and housing, and to the continuous improvement of living conditions. The States Parties will take appropriate steps to ensure the realization of this right, recognizing to this effect the essential importance of international co-operation based on free consent.
2. The States Parties to the present Covenant, recognizing the fundamental right of everyone to be free from hunger, shall take, individually and through international co-operation, the measures, including specific programmes, which are needed:

(a) To improve methods of production, conservation and distribution of food by making full use of technical and scientific knowledge, by disseminating knowledge of the principles of nutrition and by developing or reforming agrarian systems in such a way as to achieve the most efficient development and utilization of natural resources;
(b) Taking into account the problems of both food-importing and food-exporting countries, to ensure an equitable distribution of world food supplies in relation to need.

Article 15

1. The States Parties to the present Covenant recognize the right of everyone:

(a) To take part in cultural life;
(b) To enjoy the benefits of scientific progress and its applications;
(c) To benefit from the protection of the moral and material interests resulting from any scientific, literary or artistic production of which he is the author.

2. The steps to be taken by the States Parties to the present Covenant to achieve the full realization of this right shall include those necessary for the conservation, the development and the diffusion of science and culture.

3. The States Parties to the present Covenant undertake to respect the freedom indispensable for scientific research and creative activity.
4. The States Parties to the present Covenant recognize the benefits to be derived from the encouragement and development of international contacts and co-operation in the scientific and cultural fields.

Article 11 has been interpreted to include the right to safe drinking water and sanitation. The 'benefits of scientific progress and its applications' of Article 15 are understood to include engineering and medicine. However, it should be noted that most human rights are subject to limitations: 'Often some sort of balance must be struck between competing rights, values or interests. For example, freedom of information has to be balanced against privacy and confidentiality, while social and economic rights are subject to resource availability, compelling a State to make choices between claims on the public purse' [3].

Such international human rights law imposes obligations on states to respect, protect and fulfil human rights. States are required to protect individuals against human rights abuses by third parties, usually through national legislation. An exception arises from the establishment of the *European Court of Human Rig*hts, which was created as part of the *European Convention on Human Rights* [4]. All 47 Council of Europe member states are party to this Convention. Any person who considers that a state party has violated his or her rights under the Convention can take a case to the Court, and judgements are binding. Thus, the *European Convention on Human Rights* provides an uniquely high level of international protection for the rights of an individual.

7.3 Human Rights, Businesses and Engineering

The preamble to the *Universal Declaration of Human Rights* makes reference to 'every individual and every organ of society'. One of the major recent developments in 'organs of society' has been a great increase in the numbers of commercial business enterprises, including large businesses and notably transnational businesses. It is estimated that the 192 UN Member States host 80,000 transnational enterprises, ten times as many subsidiaries and millions of national firms. Many of these have engineering as an important or core part of their activities. All businesses can affect human rights. In the media, significant attention has been given to cases of transnational companies being accused of responsibility for, or complicity in, human rights abuses, often associated with activities such as the extraction of natural resources or clothes manufacture. Such concern has been especially great with regard to inadequately governed countries: as international human rights law has not imposed direct legal obligations on businesses, maintenance of human rights standards has required effective national legislation. However, transnational companies can potentially be held liable in their home countries for human rights violations caused in other countries.

At the same time, businesses have increasingly recognised that they have human rights responsibilities, and indeed that good human rights practice can bring commercial rewards:

> There is growing evidence that good [human rights] practice enhances reputation, resulting in improved staff morale, leading to a higher motivation, productivity, and the ability to attract and retain the best employees; strengthens the licence to operate, giving improved access to new markets, consumers and investors; creates more stable operating environments; and promotes better community relations [5].

As a result, there have been many initiatives seeking to clarify the responsibility of businesses. One of the most significant is the *Global Compact* launched by the UN in 2000 [6]. This is now a network of more than 10,000 participants, including over 7,000 businesses in 145 countries, labour and civil society organisations and 7 UN agencies. The *Global Compact* asks companies to 'embrace, support and enact' a set of ten principles in the areas of human rights, labour standards, the environment and anti-corruption. The first two are concerned explicitly with human rights:

> *Principle 1*
>
> Businesses should support and respect the protection of internationally proclaimed human rights.
>
> *Principle 2*
>
> Businesses should make sure that they are not complicit in human rights abuses.

Several of the other principles are also related to human rights, including the abolition of child labour, the elimination of forced and compulsory labour and the adoption of sound employment practices.

The very important culmination of this and related initiatives has been the endorsement in 2011 by the United Nations Human Rights Council of a set of *Guiding Principles for Business and Human Rights* [7].[2] These are designed to provide a global standard for preventing and addressing the risk of adverse impacts on human rights linked to business activity. They are also intended to provide tools to measure real progress in the daily lives of people. The *Guiding Principles* are the result of six years of work by the UN Secretary-General's Special Representative for Business and Human Rights, John Ruggie, involving governments, companies, business associations, civil society, affected individuals and groups, investors and others around the world. The goal of this work was to build meaningful consensus among all stakeholders about the roles and responsibilities of both states and companies with regard to the impacts of business on human rights. The *Guiding Principles* do not create new international law obligations, but elaborate the implications of existing standards and practices for states and

[2] This and other UN documents concerning business and human rights are available at [8].

businesses, integrating them in a single coherent and comprehensive form. The 31 Principles are divided into three groups:

1. The state duty to *protect* human rights (Principles 1–10).
2. The corporate responsibility to *respect* human rights (Principles 11–24).
3. Access to *remedy* when human rights are breached (Principles 25–31).

Each principle is followed by a short commentary. Particular note should be taken of the differing roles of the state and corporations. More recently, further guidance for businesses has been provided in an additional publication, *The Corporate Responsibility to Protect Human Rights: An Interpretive Guide* [9]. In these documents, the corporate responsibility is divided into *Foundational Principles* (11–15) and *Operational Principles* (16–24), with the latter divided into *Policy Commitment* (16), *Human Rights Due Diligence* (17–21), *Remediation* (22) and *Issues of Context* (23–24). These are complex documents, and hence the main purpose here is simply to draw attention to some of the Principles that are most relevant to the practice of engineering.

As the *Guiding Principles for Business and Human Rights* define a global standard of expected conduct, all engineers working in businesses should be aware of the *Foundational Principles* underlying the corporate responsibility to respect human rights, of which the first two are especially important:

> *Principle 11*
>
> Business enterprises should respect human rights. This means that they should avoid infringing on the human rights of others and should address adverse human rights impacts with which they are involved.
>
> *Principle 12*
>
> The responsibility of business enterprises to respect human rights refers to internationally recognized human rights—understood, at a minimum, as those expressed in the International Bill of Human Rights and the principles concerning fundamental rights set out in the International Labour Organization's Declaration on Fundamental Principles and Rights at Work.

These principles entail an obligation to respect human rights in all business activities. This responsibility is considered to be independent of the ability or willingness of states to fulfil their own human rights obligations. In this context, it is important to recall that the consequences for a business failing to respect human rights may be reputational and financial as well as legal. Furthermore, the human rights of certain vulnerable groups may require special attention and the UN has identified these as including: indigenous peoples; women; national, ethnic, religious and linguistic minorities; children; persons with disabilities; and migrant workers and their families. Business activities are understood to include both actions and omissions.

Businesses are expected to have good knowledge of and show that they respect human rights. This has led to the formulation of *Operational Principles*, of which the first is the need of a *Policy Commitment*:

Principle 16

As the basis for embedding their responsibility to respect human rights, business enterprises should express their commitment to meet this responsibility through a statement of policy that:

(a) Is approved at the most senior level of the business enterprise;
(b) Is informed by relevant internal and/or external expertise;
(c) Stipulates the enterprise's human rights expectations of personnel, business partners and other parties directly linked to its operations, products or services;
(d) Is publicly available and communicated internally and externally to all personnel, business partners and other relevant parties;
(e) Is reflected in operational policies and procedures necessary to embed it throughout the business enterprise.

Many engineers attain senior management positions as their careers progress, and such engineers will be involved in the formulation and approval of such a *Policy Commitment*. Indeed, their earlier experiences as practising engineers may prove very valuable in the formulation of such a *Commitment*. All engineers working in a business can be guided by their company's *Commitment*.

A crucial part of acting on such a *Policy Commitment*, and one which is very relevant to engineering work, is *Human Rights Due Diligence*:

Principle 17

In order to identify, prevent, mitigate and account for how they address their adverse human rights impacts, business enterprises should carry out human rights due diligence. The process should include assessing actual and potential human rights impacts, integrating and acting upon the findings, tracking responses and communicating how impacts are addressed. Human rights due diligence:

(a) Should cover adverse human rights impacts that the business enterprise may cause or contribute to through its own activities, or which may be directly linked to its operations, products or services by its business relationships;
(b) Will vary in complexity with the size of the business enterprise, the risk of severe human rights impacts, and the nature and context of its operations;
(c) Should be ongoing, recognizing that the human rights risks may change over time as the business enterprise's operations and operating context evolve.

Engineers are well versed in corresponding diligence with regard to matters such as technical standards, health and safety, and environmental impact. This is especially so in the design and construction of new facilities, and in their subsequent operation. For example, diligence regarding the environmental impact of new facilities will include an assessment of the impact on the surrounding population involving consultation with local communities. However, the assessment of human rights risks involves a different emphasis and new factors. Thus, the impacts on individuals from particularly vulnerable groups will need special attention. Furthermore, as human rights are concerned with the dignity of individuals and communities, subjective and cultural issues will require attention. At the same time, the ability of engineers to provide quantitative assessments of environmental quality can contribute to the promotion of human rights. Engineers need also to be aware that their activities may impact on almost all of the rights specified in the ICESCR and ICCPR, so a comprehensive approach to human rights diligence is required. Those engineers involved in contract negotiation have great opportunities to ensure that human rights issues are included and respected [10].

Even when great effort is devoted to respecting human rights, unforeseen breaches may occur. Hence, the *Guiding Principles* also give attention to *Remediation*:

> *Principle 22*
>
> Where business enterprises identify that they have caused or contributed to adverse impacts, they should provide for or cooperate in their remediation through legitimate processes.

Again, engineers are well versed in corresponding identification and remediation of breaches or potential breaches, for example regarding health and safety. Indeed, Chap. 2 identified safety as a key internal good of the practice of engineering. Maintenance of safety requires alertness, good reporting procedures, and effective identification and remediation of potential problems. The *Guiding Principles* recommend similar attention to human rights. Engineers working in large enterprises will also be familiar with corresponding procedures regarding ethics, and breaches of ethics, as specified in their company's Code of Conduct. Such Codes are often backed up by extensive procedures to support staff in the promotion of ethical conduct.

Finally, the *Guiding Principles* for corporate responsibility specify two principles concerned with *Issues of Context*. The first of these particularly addresses legal issues. It is the second that may be less intuitive for practising engineers:

> *Principle 24*
>
> Where it is necessary to prioritize actions to address actual and potential adverse human rights impacts, business enterprises should first seek to prevent and mitigate those that are most severe or where delayed response would make them irremediable.

Though all actual breaches of human rights are serious, there will often be a consensus that some breaches of human rights are more severe than others. When resources are limited, it will then be necessary to remedy the most severe first before giving attention to others. Regarding potential adverse human rights impacts, familiar approaches to risk may suggest that both the probability and severity of the impact should be given comparable weight. However, human rights experts advise that severity is paramount, understood as 'scale, scope and irremediable character' of the impact [11]. Furthermore, potential adverse human rights impacts should not be assessed using a cost-benefit analysis that compares the costs of mitigating an adverse impact to the costs of being responsible for that harm. This follows from the basis of human rights in the dignity of each individual.

Many businesses now have a formal company policy statement on human rights [12]. For example, the energy company BP published *Human Rights: A Guidance Note* in 2006 [13]. The purpose of the note is to explain what human rights means in the context of BP's activities and to provide guidance for leaders and employees:

> In keeping with our group values and code of conduct, every leader in BP is responsible for understanding how his or her activities potentially impact human rights, and for ensuring that employees have the necessary awareness, tools, and license to act in such a way that minimises potential negative impacts on human rights and furthers our commitment to mutual advantage, respect and human dignity.

The company's engagement with human rights developed after it had been falsely accused of human rights abuses connected with the security of its oilfields in Columbia in the late 1990s. This high profile case led to the company developing expertise and expert contacts in human rights, including contributing to the establishment of industry standards (oil, gas and mining) regarding respect for human rights, the *Voluntary Principles on Security and Human Rights*, the outcome of a collaboration between governments, companies and NGOs. The BP *Guidance Note* discusses the human rights of employees and local communities in the context of the *Universal Declaration of Human Rights*. It also considers good practice in terms of risk assessment prior to the physical start of projects and in terms of response plans for consideration of potential human rights violations, drawing an analogy with response plans for safety and environmental incidents. The importance of good documentation of human rights practices and of the need for training and awareness building of staff are also noted.

BP was one of the businesses that participated in the development of the UN *Guiding Principles for Business and Human Rights*. The company has stated that it is has 'begun the work that will be necessary to achieve alignment with this new framework, including commissioning an assessment of how well BP's current policy and processes align with the recommendations in the *Guiding Principles* and preparing to introduce a new human rights policy' [14]. A new company *Code of Conduct* includes more explicit reference to the rights and dignity of communities with which it interacts [15]. The company hopes that the *Guiding Principles* will help resolve some of the more difficult issues concerning business respect for human rights, such as collaboration where the company does not have a controlling interest, and where national law conflicts with internationally recognised standards.

The UN *Guiding Principles* set a minimum level of behaviour for all businesses in all situations expressed by the requirement to *respect* human rights. The UN also recognises that some enterprises may wish to go beyond this minimum and seek to *promote* human rights [16]. There may be a number of reasons for doing so that are relevant to central business objectives, such as the development of new business opportunities or to enhance the company's reputation. In some circumstances, a company may need to invest in the local provision of clean water and sanitation, healthcare and education so as to ensure a suitable work force and the support of the local community. National laws and the conditions of government contracts may also require such promotion of human rights. Furthermore, this possibility of promoting human rights is formally recognised by some companies. For example, the BP *Guidance Note* recognises that 'A company can also demonstrate leadership on supporting and promoting international human rights norms' [17].

7.4 Human Rights and the Practice of Engineering

The wide international agreement on the importance and scope of human rights that has developed since 1948 is extraordinary. Neither the *Universal Declaration of Human Rights* nor any of the later international documents provides a fundamental grounding for the significance of human rights. Even so, this agreement shows that the value of each human person is understood across the usual boundaries of our existence, such as national identity, culture and religion. Of course, there are various areas of debate, differences in emphasis and disagreement, but overall there remains a strong consensus that human rights discourse is both valid and valuable. The recent application of human rights thinking and agreement to business activities is also providing important clarifications of the responsibilities of commercial engineering enterprises and practising engineers for respecting human rights.

The human rights approach is other oriented and universal. Thus, there is a consonance between the human rights approach and the approach to the practice of engineering that has been described in the previous chapters of this book: a practice with the purposive social end described as being 'to enhance the welfare, health and safety of all' with the goal of *the promotion of the flourishing of persons in communities through contribution to material wellbeing*. Two aspects particularly warrant further comment here:

1. In Chap. 2, several characteristic internal goods of engineering that were broad in scope were identified: safety, cost-effectiveness and social and environmental sustainability. These are concerns that typically suffuse engineering activities. *It may now be suggested that the promotion of human rights should also be considered a characteristic internal good of engineering.* The many links between the ethical practice of engineering and the human rights approach suggest that this would very appropriate.

2. Such promotion of human rights would be a clear example of the expression of compassion and generosity through engineering activities. Such promotion of human rights by engineers would therefore be consonant with the key aspiration that the great technical innovation of engineering should be matched by a corresponding innovation in the acceptance and expression of ethical responsibility.

There have previously been only a few initiatives that have explicitly sought to link human rights and engineering. One of the most imaginative and challenging has been the incorporation of human rights into an engineering curriculum in Sri Lanka at a time when that country was rent by civil war. Human rights proved to be a subject with which the students engaged strongly [18]. Another analysis has recommended that professional engineers should adopt responsibility for the achievement of human rights as a means of providing a stronger focus on the social ends of the profession rather than just the technical means [19]. Very recently, the American Association for the Advancement of Science has begun an initiative to engage more engineers with the human rights aspects of their professional activities [20]. The strong current international engagement in the links between business and human rights make the present a very opportune time to develop the explicit contribution of engineers to the human rights of all.

7.5 Politicians, Power and Engineering

Engineering is in general very poorly understood by politicians and governments in Western countries, despite much effort by professional institutions and individuals. Engineering does not appear in political manifestos and official government documents very rarely explicitly refer to engineering, even when engineers can provide solutions to the problems under consideration. Indeed, very few senior Western politicians or bureaucrats have an education or practical experience in engineering. It is, therefore, not surprising that they do not understand its technical vocabulary or its scope for contributing to human flourishing. However, engineers need to find a way of communicating with politicians if engineering is to fulfil its potential for promoting human good.

In seeking to promote the ethical application of engineering, engineers first need to identify those politicians who genuinely seek the common good. This is not necessarily an easy task, at least in the UK, for many current politicians seem rather to be motivated by questions such as, ‘How can I get on?’, ‘How can I further my career?’, or ‘How can I promote the success of certain interest groups?’. Fortunately, there are politicians who are genuinely motivated by ethical concerns. One of the most effective in the UK in the twentieth century was Aneurin Bevan, a very practical proponent of social justice who also provided a succinct account of his profound political thinking [21]. His greatest achievement was to play a pivotal role, as Minister of Health, in the formation of the National Health Service, a task requiring both great ethical commitment and great political skill. As he wrote:

> No society can legitimately call itself civilised if a sick person is denied medical aid because of lack of [personal] means…The essence of a satisfactory health service is that rich and poor are treated alike, that poverty is not a disability, and wealth is not advantaged…Society becomes more wholesome, more serene, and spiritually healthier, if it knows that its citizens have at the back of their consciousness the knowledge that not only themselves, but all their fellows, have access, when ill, to the best that medical skill can provide [22].

This is a very clear statement of a goal of promoting the flourishing of persons in communities. At the same time, in his further role as Minister of Housing, Bevan very effectively promoted the construction of houses, especially for the most needy. Unusually for such a senior politician, he was greatly concerned with the quality of such housing and especially with the experience of living in such accommodation [23]. Bevan was also a very perceptive analyst of international issues. He saw the dangers of massive military expenditure, and recognised better alternatives: 'the temptation to precipitate action is obvious…The answer to social upheaval is social amelioration' [24]. He perceived the ethical demands of globalisation long before the term was commonly used: 'it is by now, I should have thought irrefutable—that most, if not all, the peoples of the world are linked together in an endless variety of reciprocal activities, then the condition of each one of us, becomes the concern of all of us. This is only the ethical formulation of an irrefragable fact' [25]. He was concerned about the depletion of natural resources long before the environmentalist movement became popular: 'It is easier to turn out the blueprints for a production line than it is to discover and then extract the precious metals with which to feed it…But the most serious immediate problem is that these raw materials are physically exhaustible and when exhausted irreplaceable' [26]. He recognised the dangers of financial speculation: 'They are pouncers, not planners' [27]. He was a strong supporter of the role of the UN. Of particular note to engineers, he was aware of the dangers of 'technical brilliance and social blindness' [28].

In short, Bevan was the kind of politician with whom engineers need to engage if they are to fulfil the ethical opportunities of engineering. Here is a type of politician with a profound ethical motivation and a prescient awareness of the needs of people in their communities and in their global relations. Crucially, here is a type of politician who is able to fulfil ethical vision through practical action. So, a key question is: 'How can the potential contribution of engineering be communicated to such a politician?'. Here it is pertinent to consider a question that Bevan asked himself at the start of his political career. Bevan was born into and grew up in a very deprived working class community. However, he did not ask himself a question such as 'How can I get on?'. Rather, as he describes it: 'A young miner in a South Wales colliery, my concern was with one practical question, where does power lie in this particular State of Britain, and how can it be attained by the workers?…The pursuit of power presented itself to us in social and not in personal terms' [29]. For the present analysis, the key word here is *power*. It is the pursuit of power that distinguishes politicians from engineers, and from ethicists. So, if engineers wish to communicate the benefits of engineering to ethically motivated politicians it could be very beneficial to speak in terms of engineering's contribution to political power.

7.6 Power Resources, Power Conversion and Realised Power

If engineers are to communicate in terms of power, they need to have some idea of the nature of power. As might be expected, this is a complex and much contested topic. To make some progress, this section will use some concepts from a recent text, *The Future of Power*, by an acknowledged expert in the field, Joseph S. Nye [30]. This text provides an account of Nye's seminal work and of related studies, mostly regarding international power. One of the simplest descriptions of power is in terms of *power resources* that may be transformed by *power conversion* into *realised power*. For example, military resources may be converted by means of war into political dominance. This would be an example of *hard power*, and as described in Chap. 3 of this book would make extensive use of engineering. Such realisation of power depends on the context. Thus, even overwhelming acquisition of military resources does not guarantee dominance, as recent wars in Iraq and Afghanistan have shown. Many other types of resource have the potential to give rise to realised power if the context is appropriate. Nye gives the examples of oil and uranium, which gave rise to realised international political power with the rise of refining industries and nuclear electricity production, respectively [31]. The extent of such natural resource based international power fluctuates with time, and such resources may cause power instability in producing countries due to resulting unbalanced economies and corrupt institutions.

In these terms, engineering may be understood as both a power resource and a means of power conversion. The availability of skilled and experienced engineers provides a very versatile power resource. As has been described in earlier chapters, engineers possess a range of knowledge, skills, techniques and technologies that have great potential for the solution of many practical problems. The same knowledge and skills provide them with an unique ability to identify problems and opportunities. However, engineering is also a means of power conversion, as the cases of oil and uranium exemplify. The development of both the petrochemical refining industries and of nuclear power generation is crucially dependent on engineering. Furthermore, engineering of vehicles and other artefacts creates a need for the refined products. It is the ability to convert natural resources into useful products and processes that realises their political power.

The relationships between ownership of resources, ownership of the means of conversion, and the need for the product or process give rise to intricate international balances of power. However, engineering may also be understood as both a power resource and a means of power conversion at the national level. Democratically elected politicians need to ensure the wellbeing of their populations so as to ensure election, and effective use of engineering, especially in the provision of infrastructure, is essential to such wellbeing. Even in non-democratic political systems, a regime that does not promote the wellbeing of the population in such ways is likely, eventually, to lose power due to civil unrest.

7.7 Military Power, Economic Power and Transnational Relations

Nye further develops his analysis of power through use of the concept of *relational power* [32]. Such relational power has three 'faces':

1. Getting others to act in ways that are contrary to their initial preferences and strategies.
2. Framing and agenda setting that promotes desired outcomes.
3. Shaping initial beliefs, perceptions and preferences.

For policy purposes, he proposes that these three faces be considered in the reverse order of this sequence. Here, an important part of Nye's analysis is the concept of *soft power*: 'the ability to affect others through the co-optive means of framing the agenda, persuading, and eliciting positive attraction in order to obtain preferred outcomes' [33]. Whereas hard power seeks coercive power *over* others, soft power seeks to accomplish goals *with* others. The soft power resources of a country include culture, political values and foreign policy. He further proposes the use of *smart power*: 'the ability to combine hard and soft power into effective strategies' [34]. Smart power may be used for any of the three faces of power. However, he favours the use of soft power wherever possible, as experience shows that this is a much more effective means of acquiring and exercising power than are force, deception or terror.

Nye considers that international power in the world is presently 'distributed in a pattern that resembles a complex three-dimensional chess game' [35]. On the top chessboard he places *military power*, which he regards as largely unipolar as the US is essentially supreme. On the middle chessboard he places *economic power*, which he regards as multipolar as there are several major players and many others gaining in importance. On the bottom chessboard he places *transnational relations* that cross borders outside of government control, which he regards as having power very widely diffused. This includes non-state actors such as transnational companies, banking, cyber-relations, terrorists and also challenges such as pandemics and climate change. According to Nye, an effective political power strategy needs to operate at all three of these levels, and each level may involve the use of both soft and hard power.

It can be noted, though Nye does not make this observation, that all three of these levels are highly dependent on the use of engineering. The essential role of engineering in military power has been described in Chap. 3. This is mostly the use of hard power, though it can lead to soft power if military resources are used for humanitarian relief, such as sometimes happens following natural disasters.

Economic power is also crucially dependent on engineering, for the world's strongest economies are those with efficient manufacturing industries. Furthermore, exploitation of natural resources and agriculture both require significant engineering input. Transnational relations also depend greatly on engineering. For example, there could be no international cyber-relations without the engineered hardware that support them and global challenges such as climate change require engineering input for their solution. Thus, it seems reasonable to propose a new category that should be of interest to politicians: *engineering power—the ability to attain preferred outcomes through the peaceful use of engineering capabilities.*

7.8 Engineering Power

Though the designation is not used, engineering power is a very important aspect of China's soft power approach to African countries [36]. The Chinese approach is described as a 'win–win' strategy: China needs resources and African countries need development infrastructure. Hence, Chinese state-owned companies have been provided with the means to develop new international business, including preferential access to finance. For such business, the principle of mutual benefit is coupled with a principle of non-interference in the internal affairs of the partner country. The approach has been most vigorously followed with Angola, where more than 150 infrastructure projects worth about US$5 billion have been financed in exchange for oil. Infrastructure engineering has included road construction, housing, hospitals, health centres, schools, irrigation systems and a fibre optic network. A long-term infrastructure development of similar value in the Democratic Republic of Congo is reported to involve the construction of 2,400 miles of roads, 200 miles of railway, 32 hospitals, 145 health centres and 2 universities, financed in exchange for copper concessions. Further agreements in Zambia, Mauritius and Nigeria involve the construction of dams, roads and railways. China also has commitments to 100 clean-energy projects in Africa, including solar and hydroelectric energy.

These projects have successfully created power with the elite politicians of these countries. They also have the potential to create power with the general population of these countries by improving wellbeing and agency through the provision of essential basic infrastructure and the creation of work opportunities, both directly and indirectly. However, such influence on the general population seems to have been less successful for a number of reasons. Most significantly, the principle of non-interference has created doubts about good governance, transparency, accountability and human rights. Only 30 % of the employment on the projects has been local, with the remainder being Chinese, which has caused friction with local people. Employment conditions have been poor and technology transfer to the partner country has not been effective. There have been concerns about environmental degradation. Furthermore, the influence of the political elite has led to unnecessary 'prestige' projects such as a new town for half a million people close to the Angolan capital Luanda which is largely unoccupied as local people cannot afford the accommodation, as well as football stadiums and basketball stadiums. Additionally, some of the engineering is reported to be of low technical quality [37].

The prominent use of engineering power by China is in remarkable contrast to the ignorance about the potential of engineering shown by most UK and other Western politicians. This use is surely related to eight out of nine members of the key Chinese Politburo Standing Committee up to November 2012 (the seventeenth) having engineering qualifications. The new Committee (the eighteenth) that took over at that time has two members out of seven with engineering qualifications, including the leader, General Secretary Xi Jinping, who studied chemical engineering at Tsinghua University [38]. In contrast, not one of the twenty-two present UK Cabinet members has similar level qualifications in engineering, or in science. Nevertheless, such UK politicians will certainly understand the language of power even if they have little understanding of engineering. Hence, the importance of promoting the concept of engineering power.

The defects of the Chinese use of engineering power in Africa show that there is considerable scope for better practice. Such projects should be conducted with attention to good governance, transparency, accountability, human rights and technical excellence. Power will then be achieved with both the political elite and the general population. In the longer term, it is power with the latter that is more effective. Moreover, engineering power is just as relevant in national as international politics, for it can profoundly affect the wellbeing and agency of all people, and hence the election of politicians who use it wisely.

A further key feature of Nye's analysis is that power is diffusing from governments to non-government actors, many of whom operate freely across state borders. This has been happening for some time. Indeed, Nye suggests that oil companies averted further escalation of the 1973 Middle East war by redistributing traded oil, mostly acting out of their own interest to maintain stability, and hence preventing an economic conflict from leading to increased violence [39]. This is an example of engineering businesses themselves wielding considerable political power. Indeed, engineering businesses, and hence their engineers, may generally have considerable latent political power, for they have physical resources, knowledge resources and skill resources, and the ability to use them to realise power.

Arguably the greatest diffusion of power to engineers has occurred in information technology, what has been termed 'cyberpower'. As Nye notes, in an information age outcomes may be decided by 'whose story wins' [40]. The flow of information around the world is very dependent on engineering skills. Through the engineering of hardware and software it is possible to control who can access information, when it can be accessed and to what use it can be put. Indeed, even the content of information can be controlled though engineering. Some of these factors are the subject of consensus through bodies such as the Internet Engineering Task Force, the World Wide Web Consortium and the Internet Corporation for Assigned Names and Numbers. However, governments, non-governmental bodies and individuals may all have an interest in influencing the flow of information. Sometimes the intents of such actors may be malicious or criminal, posing threats to human wellbeing, national security or commercial confidentiality. As a result of all of these factors, engineers have great power and great responsibility. For example, the internet is currently structured to allow ease of use but may need re-engineering to prevent malicious misuse. There is also a strong case for regarding cyberspace as a global common good, as are the earth's biosphere and outer space. The health of all of these shared spaces depends on the responsible use of engineering power.

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Chapter 8
Future Perspectives

8.1 Introduction

The preceding chapters have addressed the greatest challenge facing contemporary engineers: can the great technical innovation of engineering be matched by a corresponding innovation in the acceptance and expression of ethical responsibility? The description of this challenge began with an elucidation of the nature of engineering that made use of key concepts from leading philosophers. Three ways in which engineers can accept and express ethical responsibility were then considered: engineering for peace, engineering for health and engineering for development. Strategies for promoting such acceptance and expression of the ethical nature of engineering have been described: the acceptance of personal responsibility and participation in supporting social structures; and convincing others through human rights approaches and the elucidation of engineering power. This chapter will be concerned with the future prospects for increasing the acceptance and expression of ethical responsibility by engineers, particularly in an extended time frame. Each of the themes of the preceding chapters will be addressed, including consideration of some underlying issues.

8.2 A Philosophical Analysis of the Nature of Engineering

Engineering has been described as a practice with a complex structure involving goals, internal goods, external goods, virtues, institutions and systematic extension. The success of such a practice is dependent on appropriate attention being given to all of its significant features. One of the greatest dangers for the practice of engineering is that too much emphasis is given to the external goods of technological artefacts. Such artefacts are an important feature of engineering, but they are only one of its characteristic features. There has been a tendency to view the production of such artefacts as being the goal of engineering. However, this is to neglect the real goal of the practice of engineering, expressed in the present work

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as the promotion of the flourishing of persons in communities through contribution to material wellbeing. It has been proposed that such flourishing of persons in communities is best understood in terms of the capabilities of beneficiaries, both wellbeing and agency. The inclusion of agency is particularly appropriate for an enabling activity such as engineering. Furthermore, the specific knowledge and skills of engineers have been understood as giving rise to an opportunity of professional capabilities that can guide the prioritisation of engineering activities. In circumstances of extreme injustice, such an opportunity may be better considered as an obligation of professional capabilities.

On this understanding, engineering is a profession that has ethics at its core. Indeed, this is the view of many practising engineers. However, a major barrier to the realisation of the great ethical opportunities of engineering is that many university engineering courses remain narrowly technical in scope. This has two major detrimental consequences. First, ethically motivated and scientifically able young people are not attracted to study engineering, instead opting to study professional courses where the contribution to human flourishing is more immediately apparent, such as medicine. Second, students completing university engineering courses often have a poor appreciation of the ethical opportunities arising from their new technical knowledge and skills.

Some progress in making the ethical core of engineering clearer to students is being made. For example, the Royal Academy of Engineering's Teaching of Engineering Ethics Working Group has done much to promote the incorporation of ethics into engineering courses through activities such as a programme of seminars and the production of *An Engineering Ethics Curriculum Map* [1]. Also, the UK Department for International Development has funded an imaginative programme to stimulate the incorporation of knowledge of global development priorities within university engineering education [2]. Furthermore, the European Society for Engineering Education, an academic association, has done much to raise awareness and promote new initiatives though meetings, publications and its Working Group on Ethics in Engineering Education. These are all very welcome and valuable initiatives. However, they are mostly concerned with incorporating ethics teaching within the current structures of engineering courses. Real progress in promoting engineering as a thoroughly ethical activity may require more radical change. For example, it has been suggested that university engineering departments should be concerned, 'not only with the training and assessment of their students giving them ample opportunities to build strong foundations of technical expertise and develop leadership qualities of inventiveness and risk-taking, but also with nurturing in them intellectual qualities, such as compassion, modesty and honesty and a sense of adventure with a strong community sense' [3].

This issue of the broadening of the intellectual basis of engineering education is crucial to the realisation of the expression and acceptance of ethical responsibility by engineers. It would be beneficial not just to reform but rather to transform engineering education. A distinction that is useful in describing the direction in which engineering education should move is that made by Emmanuel Levinas between *totalizers* and *infinitizers* [4]. *Totalizers* seek control of understanding by focusing on closed orders of knowledge. Much of contemporary engineering education has such a tendency, focusing particularly on certain types of technical knowledge in a way that can discourage innovative thinking. *Infinitizers* seek creative advance though use of the imagination in ways that are essentially exploratory rather than definitively explanatory. There is a real need to encourage such openness to different types of knowledge and such imaginative thinking among young engineers. This should apply not only to technical matters but also to ethical and cultural matters.

The distinction between totalizers and infinitizers provides a basis for Levinas's approach to ethics, which was described in Chap. 1. Thus, he considers a totalizing attitude as being concerned with the self and its wellbeing, whereas he considers an infinitizing attitude as leading to concern for others. The need for such openness to ethics and culture in education has become especially necessary in recent years due to the increasing secularisation of society and due to the superficiality of much modern popular culture. An engineering academic who was struggling to engage students with ethical aspects of the subject succinctly expressed an outcome of these trends, 'The trouble is that students no longer know of the *Sermon on the Mount*'. This was not a religious comment; the academic was not sympathetic to organised religion. It was an ethical and cultural comment, lamenting that the students lacked knowledge of an important feature of Western culture, and, therefore, lacked knowledge of concepts and vocabulary that would have facilitated their engagement with ethical matters.[1] It seems that Hannah Arendt's criticism of engineers that was noted in Chap. 1 retains some validity.

This has not always been the case, as the work of Pavel Florensky described in Chap. 1 demonstrates. Nor is it necessarily the case now, and this can be shown by the lives of modern engineers who could serve as inspirations to students. Consider, for example, the life of Ian Bowler, described as 'Legendary oil and gas pipeline engineer; serious sailor; poet, short story writer, flamenco guitarist, naturalist, falconer, expert cook, raconteur and polymath' [5]. Bowler founded the International Management and Engineering Group (IMEG), and his greatest engineering achievement was the design and construction of a gas pipeline in Iran from Ahwaz, near the Persian Gulf, to Astara, a Soviet border town on the Caspian sea. The pipeline was 1260 km long and 42 inches in diameter, with an additional 800 km of 6–30 inch gathering lines, 17 compressor stations and high gas sweetening and dehydration plant capacity. It was the first high-pressure gas pipe at high altitude, running over the Zagros mountains. With a value of US$678 million, it was one of the largest engineering projects in the world when completed in the early 1970s. Bowler's ability to win such a contract was enhanced by his political skills and knowledge of Iranian culture and society. For example, at about the same time he wrote a definitive monograph, *The Predator Birds of Iran*. Many other innovative projects followed and IMEG remains a leading force in advanced

[1] The *Sermon on the Mount* provides a summary of New Testament ethical teaching (Gospel of Matthew, Chaps. 5, 6 and 7).

oil and gas pipelines [6]. It is such culturally diverse engineers who can stand as exemplars in the broadening of engineering education.

8.3 Engineering for Peace

Finding imaginative ways to contribute to genuine peace is an urgent challenge for engineers. This may be a difficult task, for there is in Western culture 'a pervasive, subconscious *warism*—an uncritical presumption in modern society that war is morally justifiable, even morally justified' [7]. This is clearly demonstrated by national spending budgets, for budgets are ethical documents: they show where priorities really lie. Thus, the respective diplomatic budgets of both the US and UK are only about 7 % of the respective military budgets [8, 9]. In the UK, funds specifically allocated for peacekeeping in the diplomatic budget, mostly to meet international obligations, are only about 2 % of the military budget [10]. Furthermore, such peacekeeping expenditure is mostly used to intervene in existing conflicts rather for the prior promotion of genuine peace.

As noted in Chap. 3, highly automated systems such as weaponised drones are the military development that pose one of the greatest future challenges to the ethical practice of engineering. These allow remotely controlled or even automated killing at great distances, thereby bypassing the most important motivator of ethical conduct, the proximity of the other person. Furthermore, the proponents' claims of the efficacy of such technology are very questionable. Thus, a recent very detailed report has concluded, 'In the United States, the dominant narrative about the use of drones in Pakistan is of a surgically precise and effective tool that makes the US safer by enabling "targeted killing" of terrorists, with minimal downsides or collateral impacts. This narrative is false' [11]. The main conclusions of the report are:

(1) While civilian casualties are rarely acknowledged by the US government, there is significant evidence that US drone strikes have injured and killed civilians.
(2) US drone strike policies cause considerable and under-accounted for harm to the daily lives of ordinary civilians, beyond death and physical injury.
(3) Publicly available evidence that the strikes have made the US safer overall is ambiguous at best.
(4) Current US targeted killings and drone strike practices undermine respect for the rule of law and international legal protections and may set dangerous precedents.

The report recommends a fundamental re-evaluation of the use of such weapons.

The dire effects of the use of weapons on civilians have been described in Chap. 3. However, a major finding of the recent report is that summarised in the second conclusion: that such weapons have a severely detrimental effect on the wellbeing and agency of individual civilians and their communities even if the missiles of the drones are not fired. The drones hover over communities 24 h a day and may strike any person or location without warning. This is a form of terror that psychologically traumatises the entire population. Severe disruption is caused to community life as the population avoids gathering in groups. Children are kept home from school and religious ceremonies are avoided. When missiles are fired, the practice of repeating strikes kills rescuers and discourages humanitarian assistance.[2]

The development of drones is evidence of the insidious presence of warism within some sections of the engineering profession. Furthermore, such development poses a growing threat to the ethical practice of engineering, for the increasing automation of such weapons increases the role of engineers in warfare: engineers become *the* essential professionals for such warfare, more necessary than even military personnel as conventionally understood. However, the case of drones makes apparent two important themes if the ethical practice of engineering is to succeed in the future:

(1) Drones are an example of a type of technology that has many potential applications that could greatly contribute to human flourishing, such as monitoring of the natural environment, monitoring of agricultural crops and providing information in difficult environments following catastrophes. However, such uses are being neglected due to the present dominant focus on military applications. This is an example of the opportunity cost (loss) of military engineering. Drones may in fact provide an excellent case for redeployment of knowledge and skills in the pattern of a Lucas plan as described in Chap. 6.
(2) The description of the practice of engineering in Chap. 2 identified certain internal goods of engineering that were broad in scope: safety, cost-effectiveness and environmental sustainability. These are essential aspects of engineering that all engineers regard as being of key importance to the success of the practice. In Chap. 7 it was suggested that the promotion of human rights should also be regarded as a characteristic internal good of engineering. *It may further be suggested that the promotion of peace should be regarded as a characteristic internal good of engineering*. The promotion of peace may be viewed as a natural extension of the paramount importance of safety in all engineering activities. Furthermore, as described in Chap. 3, such promotion of peace should be based on active peacemaking: the provision of practical solutions that resolve the underlying roots of conflict, committing communities in potential conflict to common non-violent projects of benefit to all.

Such approaches have been termed *Peace Engineering*. In a recent publication, 16 engineers, from world-leaders to students, have described their commitment to

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[2] Though the psychological damage is less, it is worth noting that empathetic civilians elsewhere whose lives are disturbed and disrupted by the developmental testing of such drones also suffer trauma from knowledge of their ultimate use [12].

such use of engineering in the promotion of peace. Some describe intensely practical activities, others elucidate the conceptual basis of such work. Some describe lifetimes of realised contributions, others describe work in progress or challenging aspirations [13]. Their vision is that all engineers will become committed to prioritising the peace of communities.

8.4 Engineering for Health

Some of the greatest opportunities for the ethical practice of engineering arise from the increasing interaction with healthcare. Chapter 4 considered the examples of assistive technologies, telehealthcare and quasi-autonomous systems. A strong facilitator of ethical practice in such work is that the engineer is usually in much closer contact with the beneficiary than is often the case. The direct experience of the increased flourishing of beneficiaries can be a very strong motivator of ethical action. Such work also exemplifies the benefits of considering the agency of beneficiaries in addition to their wellbeing: 'What can the person do?' is a question that can stimulate innovative approaches. This is particularly important in the maintenance and promotion of genuine interpersonal relationships for persons who may be experiencing physical and mental restrictions, such as the very elderly.

Interaction of engineers with other professions can also make engineers aware of alternative approaches to matters that have previously been considered core engineering activities, such as transport. Engineering approaches to transport have tended to emphasise the ability to travel. Such approaches have often given a high priority to the economic benefits of advanced transport systems, balanced by concern for detrimental environmental effects. Most recently there has been special concern for maintaining or improving the ability to travel whilst reducing CO_2 emissions. However, Chap. 4 considered a proposal by the British Medical Association (BMA) that greater attention should be given to the ability to access services and destinations, preferably by active transport such as walking or cycling. Underlying this proposal were concerns about the detrimental health effects of motorised transport, including accidents and illness caused by pollution, and the many physical and mental health benefits of active transport. The BMA proposals require that more attention be given to safe and agreeable outdoor spaces in local built environments, which have the additional benefit of promoting interpersonal interactions. Such proposals are consonant with the ethical engineering goal of the promotion of the flourishing of persons in communities.

Adopting the BMA approach of prioritising an ability to access would have important implications for the design of transport in local environments. However, even with excellent local access to services, people may still need to access more distant destinations. An active transport approach suggests that such long distance travel should preferably be by public transport, as this usually involves some physical activity. In mainland Europe, China and Japan there has been much development of high-speed rail networks for such purposes, and there has been much discussion and some development of high-speed rail in the UK.

Recent discussion in the UK has focused on proposals for a high-speed link between London and the West Midlands (HS2). The case made by proponents of the link has been primarily economic, considering three types of factors: direct benefits and 'disbenefits' to users of the network, 'wider economic benefits', and other economic impacts arising from land use changes [14]. The case involves rather complex economic predictions, but there is a key driver: 'As most people on HS2 would most likely be existing rail users, the key driver of the economic case is the growth in the number of long distance rail trips' [15]. As such predictions require long-term assessment of passenger behaviour, and the somewhat arbitrary assignment of monetary value to different types of behaviour, such as time spent travelling, they are rather speculative. Independent engineers have also expressed concern about some of the engineering assumptions underlying the project. For example, that 'the infrastructure design speed of 400 km/h seems to have been chosen without much justification, in terms of either cost or energy use' and that 'we cannot see any justification for the claim that HS2, as proposed, will reduce [carbon] emissions' [16].

Underlying the background to the case are changing patterns of personal travel in the UK. Thus, in the period 1972–2009, the number of trips made on average by each person has remained relatively unchanged but the length of each trip, and hence the total distance travelled, has increased by about 60 % [17]. The case for high-speed rail travel is to a significant extent dependent on facilitating this ability to travel greater distances. However, such an increase in average distance travelled for each trip may reflect a decreasing ability to access desirable services and destinations by active transport. Hence, a greater focus on ability to access would suggest that more attention should be given to improving the access to local services and destinations by active transport, and also to the provision of more convenient local rail connections, or other public transport, to access services that are not available in the immediate vicinity. That is, considering the broader aspects of human flourishing promoted by a focus on ability to access can lead to very different transport policies compared to a focus on a narrower aspect of human flourishing such as ability to travel.

Fundamental to all of these differing interactions between engineering and health is a need for engineers to maintain awareness of the many influences of their activities on the lives of others. Health has physical, mental, spiritual and social aspects, and each of these may be affected by the engineered environment in which people live.

8.5 Engineering for Development

The application of engineering for development involves huge challenges and huge opportunities. Substantial contributions have already been made. For example, there has been significant progress towards meeting the Millennium Development Goals [18], and engineers have contributed much to this. Many lives have been saved and many lives improved, though achievements have been unequally distributed across and within regions and countries. At the same time, there have been frustrations and failures. An insightful account of some of these difficulties has considered the 'Kibera conundrum', Kibera being the largest slum in Africa, with a population of about 1 million:

> The Kibera slum is 5 min from the centre of Nairobi in Kenya, one of the wealthiest cities in Africa and also the hub for humanitarian aid in the region. Over the years, hundreds of aid agencies have poured energy and resources into Kibera, yet there is still no running water or power, families live in one-room huts and children play near open sewers. Why does it seem that aid makes so little difference in a place like this? [19].

In Kibera, some agencies such as Médecins Sans Frontières provide vital medical care, but others appear to be 'briefcase NGOs' set up to access funding but which exist only in name. Much of the help that does reach Kibera seems to address the symptoms of poverty rather than tackling the causes.

Further international initiatives are being considered and it is important that engineering plays a full role in these. Most significantly, the UN is already planning its post-2015 agenda [20] to follow the Millennium Development Goal initiative (which runs until 2015). Current planning envisages a more holistic approach. Three fundamental principles are suggested: *respect for human rights*, *equality* and *sustainability*. Four interdependent dimensions are being considered: *inclusive social development*, *inclusive economic development*, *environmental sustainability* and *peace and security*. It is suggested that the existing global partnership needs to be reshaped to avoid the perception of it being a donor-recipient relationship and that a full range of actors should be engaged. Sustainable development goals with a high degree of policy coherence at the global, regional, national and sub-national levels will be required. The vision is of a transformative people-centred approach. Engineers should give close attention to such future UN initiatives, for they are likely to require significant engineering input and to be consonant with the ethical goals of the profession described in the preceding chapters.

Such major initiatives provide opportunities for correcting some of the imbalances that have arisen in development activities. When such activities began about 60 years ago they were small scale and carried out by individuals with an intimate knowledge of the cultures in which they were working [21]. As such activities have increased in scope they have become an 'aid industry' which has to a certain degree developed an interest in its own sustainability to the detriment of those in real need. This is one of the reasons for the Kibera conundrum. Another unfortunate consequence has been that aid has in some cases created a culture of dependence in the developing countries. As a result, projects have been successful while financial support continues but have collapsed when external funding has come to an end. A key factor in such collapses has been identified as a failure to engage the attitudes and skills of local people in the success of the projects [22]. That is, in terms of the analysis of Chap. 2, the projects have focused on the wellbeing of beneficiaries but have failed to promote effectively their agency. Thus, a key feature in the future ethical practice of engineering for development should be to ensure that work is undertaken in partnership with and with the participation of local people so that they can accept responsibility for the long-term success of projects. This should include the long-term local financial sustainability of the project.

If such approaches are to succeed in the longer term, it is essential to engage engineering students and young professional engineers in such activities. This is specifically a goal of the international organisation Engineers Without Borders, and its priorities are consonant with those of the present analysis [23]:

> *Holistic Engineering*—we work with an interdisciplinary approach that takes into consideration the local knowledge, economy, culture and environment.
> *Active Partnerships*—we build long-term relationships and work in collaboration with communities and local organisations.
> *People Participation*—we believe in demand-led development and participatory change.
> *Small Footprint*—we want to adopt a sustainable use of natural resources and minimise any impact to the local environment, biodiversity or global climate.
> *Appropriate Technology*—we adapt existing low-risk technology and apply modern engineering methods.

Furthermore, all engineers can contribute to development by participation in initiatives such as the Technology Exchange Lab, an online platform for the sharing and discussion of ideas for innovative, locally implemented solutions to problems of poverty and sustainability [24].

8.6 Personal Responsibility and Supporting Social Structures

Chapter 6 provided strong arguments for the acceptance of ethical responsibility by individual engineers. It was also noted that working environments can constrain the practical expression of such responsibility. For this reason it can be very beneficial for engineers to participate in a base community that promotes compassionate ethical discourse and that stimulates ethical action. Examples of two types of such community were considered: trade unions and faith communities. These examples showed how both types of community could promote the imaginative expression of ethical responsibility in engineering activities. It can be valuable to assess whether there are also ways in which the core institutions of engineering such as university departments, professional associations and commercial enterprises can further seek to promote the ethical expression of engineering.

Earlier in this chapter, it was proposed that there was a case for radically reforming the teaching of engineering at universities so that curricula based on closed systems of knowledge were replaced by curricula encouraging students to seek creative technical and ethical advance though use of the imagination in ways that are essentially exploratory rather than definitively explanatory. Some progress in this direction is already being made through the process of accreditation whereby the professional associations ensure best teaching practice and encourage course innovation. For example, the Institution of Chemical Engineers now expects that students acquire the knowledge and ability to handle broader implications of work as a chemical engineer, including in the case of ethics [25]:

- Recognise ethical issues related to engineering and to an engineering situation.
- Recognise ethical responsibilities of engineers.
- Suggest ways to deal with ethical issues in engineering.
- Illustrate the ethical dimension of practical engineering.
- Undertake an ethical audit.
- Discuss ethical dilemmas in engineering.
- Justify an ethical stance.
- Articulate ethical problems in engineering.
- Reach an ethically justified practical solution to an ethical problem with an appropriate plan of action.
- Propose policy relating to ethical questions in engineering.

Furthermore, the engineering associations have taken many initiatives to promote the ethical practice of engineering among working professional engineers. For example, the Royal Academy of Engineering has undertaken many activities in connection with the development of the *Statement of Ethical Principles* and the *Engineering Ethics Curriculum Map*. Again, the Institution of Civil Engineers has been very active in promoting engineering for development, as was described in Chap. 5. Such activities are hugely valuable. Nevertheless, they cannot replace the benefits of participation in a base community that is independent of the profession. Two important limitations may be mentioned. First, professional associations are by definition groupings of people who have much in common. The members typically do not have the diversity in age, social background and life experience that can promote a broad ethical sensitivity to the needs of others and that can hence create a challenge to the ethical assumptions of the workplace. Second, professional associations have an interest in their own sustainability and are thus susceptible to influences, financial and otherwise, of commercial enterprises linked to their profession. This can limit the open discussion of certain significant ethical issues. For example, professional engineering associations only very rarely question the huge commitment of financial resources and engineering skills to weapons development. Nor have they actively promoted the use of engineering for the non-military resolution of the root causes of conflict. These omissions are undoubtedly strongly influenced by the carefully cultivated advocacy, both overt and insidious, of weapons companies.

However, highly motivated individual engineers may have scope for creating enterprises that are both technically and ethically innovative, possibly even in the apparent absence of explicit participation in a base community. An example is W. L. Gore and Associates [26], a privately owned company with 10,000 employees in 30 countries and more than US$3 billion in annual sales. International surveys consistently rate the company as an excellent employer. The company was founded in 1958 by a chemical engineer, Bill Gore, and his wife Genevieve, and was substantially expanded under their son, Robert Gore, also a chemical engineer. Most of the company's products are based on expanded polytetrafluoroethylene (ePTFE). It is best known for the fabric Gore-Tex, but is also strong in fields such as medical devices, electrical insulators and chemical processing. The products contribute much to human flourishing through the promotion of both wellbeing and agency.

Two features of the company are especially noteworthy in the present context: its lattice organisation and its culture principles. The term lattice organisation describes a comparatively loose organisational structure that is not strictly hierarchical in the sense of conventional corporate practice [27]. The basic idea is that each employee ('associate') and the team to which they belong can interact with every other employee and team, and the total number of employees at a given plant is kept to about 200 so as to maintain a dynamic of free interaction. Bill Gore described the rationale in the following way:

> A lattice organization is one that involves direct transactions, self-commitment, natural leadership, and lacks assigned or assumed authority… Every successful organization has a lattice organization that underlies the façade of authoritarian hierarchy. It is through these lattice organizations that things get done, and most of us delight in going around the formal procedures and doing things the straightforward and easy way [28].

So, there is a structure, but it is one that evolves naturally. Or that is the ideal, for W. L. Gore and Associates has a Chief Executive and other formal positions.

An aim of the lattice structure is to promote an attitude of mutual responsibility among all employees. This is promoted by the four culture principles on which the company operates [29]:

> *Freedom*—The company was designed to be an organization in which associates can achieve their own goals best by directing their efforts towards the success of the corporation; action is prized; ideas are encouraged; and making mistakes is viewed as part of the creative process. We define freedom as being empowered to encourage each other to grow in knowledge, skill, scope of responsibility and range of activities. We believe that associates will exceed expectations when given the freedom to do so.
>
> *Fairness*—Everyone at Gore sincerely tries to be fair with each other, our suppliers, our customers and anyone else with whom we do business.
>
> *Commitment*—We are not assigned tasks; rather, we each make our own commitments and keep them.
>
> *Waterline*—Everyone at Gore consults with other associates before taking actions that might be 'below the waterline'—causing serious damage to the company.

These concepts of freedom, fairness, commitment and waterline combine prioritisation of ethical responsibility and practical effectiveness.

It is interesting to compare the work practices at W. L. Gore and Associates to those of Benedictine business practice described in Chap. 6. The most noticeable difference is that the Gore practices do not explicitly arise from a base community that has values external to those of the business. Bill Gore's ideas seem to have originated from his reflection on his previous work experiences at a large chemical company. However, there are also a number of notable likenesses. First, both Gore and Benedictine practices seek to employ the whole person and seek to promote personal responsibility. Second, all persons in the organisation are valued for the contribution that they can make, according to their abilities rather than according to their status. Third, the working community acts as far as is possible on a basis of consensus. Fourth, both practices take a long-term view of business. Fifth, both practices give rise to sustainable businesses based around the excellence of the products.

The engineering business practices of both W. L. Gore and Associates and Benedictine communities have so far been more studied than emulated. However, it is very encouraging that enterprises that are both ethically and technically very successful can arise on the basis of very different founding principles. They should be an inspiration to all seeking to promote the ethical practice of engineering.

8.7 Convincing Others: Engineering for Human Rights and Engineering Power

Engineers who wish to promote imaginative innovation in the acceptance and expression of ethical responsibility in their profession need also to convince decision makers and society in general of the validity and practicality of their ethical vision. As discussed in Chap. 7, convincing Western decision makers can be a difficult task as they generally have a very poor knowledge of the technical scope of engineering and its potential to promote human flourishing. It was proposed that describing such potential of engineering in terms of a human rights approach could be productive, as there is broad international consensus on the importance of human rights. This consensus is supported by a legal framework. Furthermore, there is increasing international awareness of the responsibility of businesses to respect and promote human rights. It was also suggested that it would be beneficial to present the scope and potential of engineering to politicians in terms of political power. It is the pursuit of such power that distinguishes politicians from engineers, and from ethicists.

More radically, engineers could themselves become more fully engaged in political activities. For example, a perceptive analysis of current approaches to engineering ethics has led Eddie Conlon to conclude that a key issue confronting engineers is how to change the economic and social context in which they work so that it enables rather than constrains ethical approaches to engineering [30]. This would require that engineers learn how to evaluate public policy and how to make effective proposals for change. Hence, engineers would need to gain an understanding of the processes of technical and policy change, including social, political and economic factors. It would be beneficial for engineers to build alliances across society with the aim of promoting the kind of changes required. This is a long-term approach that Conlon envisages could begin by '[providing] students with a sense that change is necessary and possible and that there are alternatives to market based systems which constrain the activities of engineers' [31].

Another long-term approach to promoting the ethical practice of engineering is to consider the legal framework in which engineers and engineering enterprises operate. The underlying idea is that the acceptance and practical expression of ethical responsibility by individual engineers would be promoted if there was harmony between such expression and the demands regarding ethically responsible conduct placed on the organisations in which they work. Thus, in an article with the very apt title of *Good Engineers Need Good Laws*, Henk Zandvoort has considered three important legal issues: the right to be informed versus the right to secrecy; liability for potentially harmful effects; and responsibility and liability of and in organisations [32]. He proposes the direction of a number of changes to law that would enable and safeguard ethical and socially responsible conduct of engineers. More recently, Zandvoort has focused more particularity on changes needed to be made to the law of liability:

> [C]urrent liability law does not live up to requirements that are necessary for peaceful human coexistence and progress. These requirements are the requirement of informed consent and the requirement of liability in the absence of informed consent. Taking into account that scientific and technological activities are regulated on the basis of national political decision making using majority rule, these requirements imply that the default liability rule for these activities in the legal systems should be unconditional (absolute, strict) and unlimited (full) liability. Actual liability law does not live up to these requirements [33].

Some of the conclusions of Zandvoort's analysis are very far reaching, such as the need to move political decision making closer to an ideal of an agreed consensus. He also emphasises that engineers have a responsibility to play an active role in helping to shape the context in which they work in all possible ways.

Both Conlon and Zandvoort argue that substantial social change is necessary if engineering is to have the opportunity to fulfil its potential contributions to the promotion of the flourishing of persons in communities. Such social change is an admirable objective. Furthermore, the initial steps in the direction of change that they propose are certainly achievable. However, engineers need to think carefully about how they may best contribute to promoting the changes necessary in the longer term. An achievable means for many engineers would be to participate in social movements that can benefit from engineering knowledge and skills. A social movement involves a grouping of individuals and organisations focused on a specific social issue. There are several existing social movements with aims consonant with the ethical practice of engineering, including the peace movement, the environmental movement, the anti-poverty movement and the human rights movement. Indeed, many engineers are already active in such movements and an increase in such participation would be very beneficial.

However, if there is really a strong desire to promote the ethical practice of engineering wherever it has valuable capabilities to contribute, maybe a case can be made for the creation of a movement based specifically on the profession. Such a movement could aim to convince decision makers and society in general of the ability of engineering to enable socially beneficial change. It might initially seem bizarre to consider such a movement, but other professions are also considering the possibility. For example, George Alleyne, Director Emeritus of the Pan American Health Organisation, has proposed a social movement to respond to the worldwide pandemic of non-communicable diseases [34].

A study of one of the most successful social movements, the campaign to abolish British involvement in slavery, has identified the following key 'lessons' [35]:

- What seems impossible can be done—and in a comparatively short time.
- The leaders and followers need deep belief in the cause.
- A connection between the issues and people's everyday lives is essential.
- The course of the movement is unlikely to be smooth—and may well look hopeless at some point.
- Powerful, first hand accounts of the issue are invaluable.
- Cases that shock and capture the problem and the public's attention may be crucially important—even if swept to one side by the authorities.
- Social movements should pick an achievable aim and be businesslike.
- Evidence, lots of it and of high quality and impact, is important.
- Performance (perhaps these days through television or social media) with stories and props is needed for success.
- Successful movements have different sorts of leaders with different skills, but they must work together.
- An important person, perhaps a politician, who 'needs an issue for his or her own advancement' can be very useful.
- Action must be constant and on many fronts.
- Iconic pictures can be stunningly effective.
- Evidence must be substantial, multifaceted, strong, clear and speak for itself.
- Boycotts can be powerful.
- It's important to be tactically shrewd.
- Success is unlikely to be complete.

Consideration of these 'lessons' shows that many of them are attainable for the ethical practice of engineering. Most notably, the supporting evidence is very clear and engineers have the organisational skills to launch and run such a campaign. However, it is important that the leading participants in such a movement should be individual engineers who have a strong personal commitment to the ethical practice of the profession. As discussed earlier in this chapter, internal priorities and external influences may compromise the freedom of action of existing professional engineering associations.

There is already progress being made in this direction. The UK-based organisation Scientists for Global Responsibility (SGR) aims to 'promote science, design and technology that contribute to peace, social justice, and environmental sustainability' [36]. Its activities are focused on four main issues: security and disarmament; climate change and energy, including nuclear power; who controls science and technology; and emerging technologies. Its members include engineers, though its activities seem to have been mostly directed towards science and scientists, as the organisation's name suggests. SGR is affiliated to the International Network of Engineers and Scientists for Global Responsibility (INES), an European organisation that aims to promote global responsibility for peace and sustainability [37]. The aims of INES are: abolition of nuclear weapons; promoting the responsible and sustainable use of science and technology; implementing ethical principles in the education of scientists and engineers; and promoting disarmament for sustainable development. The activities of INES also seem to have had a somewhat greater focus on science than on engineering.

One option for engineers is to engage more extensively with existing organisations such as SGR and INES. Collaboration of ethically motivated engineers and scientists in such organisations can have great benefits as they have many common interests. Increased engagement could strengthen the engineering activities of these organisations. However, some care is also needed due to the differing natures of engineering and science, as discussed in Chaps. 1 and 2. Moreover, as described in Chap. 6, an engineer whose work fails to benefit humanity practically has failed as an engineer. It is less clear that a scientist whose work so fails to benefit humanity practically has failed as a scientist, at least for the case of pure science (as all knowledge could be considered a benefit). Furthermore, as discussed in Chap. 4, the socially purposive practice of engineering has much to gain from collaboration with healthcare professionals, who do not seem to engage greatly with organisations such as SGR or INES. Therefore, a second option also needs serious attention: the creation of an organisation specifically focused on engineering that would allow engineers to build alliances with all those who can help promote the ethical practice of the profession. In this context, the developing activities of the Engineering, Social Justice, and Peace (ESJP) international network [38] are very encouraging.

8.8 Concluding Personal Challenge

This book opened with a challenge in the form of a question: *can the great technical innovation of engineering be matched by a corresponding innovation in the acceptance and expression of ethical responsibility?* The analysis and practical examples have shown that the question can be answered in the affirmative for important aspects of human endeavour, such as peace, health and development. However, such acceptance and expression of ethical responsibility is not easy. It requires supporting social structures. It requires effort to convince politicians and other decision makers of the benefits of the ethical practice of engineering. Most of all, it requires the professional expression of imagination, compassion and generosity by every engineer.

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