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Engineers, Society, and Sustainability

Sarah Bell

SYNTHESIS LECTURES ON ENGINEERS, TECHNOLOGY, AND SOCIETY

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CHAPTER 7

Engineering, Technology and Ethics

Sustainability presents a particular challenge to the engineering profession. Moving beyond ecological modernism and efficiency, to more fundamental changes in the relationships between humans, technology and nature requires a new understanding of engineering and the impacts of technology. Engineers are the professionals most associated with technological systems and engineering decisions made during design, construction and manufacture of new technologies have lasting implications for the use and lifecycle of technologies and infrastructure. Engineers and philosophers have reflected extensively on the ethical implications of engineering actions and decisions. Sustainability, like many engineering problems, is a moral as well as a technical challenge. Designing ecologically efficient systems can be a presented as merely a technical problem for engineers, but it is part of a wider ethical challenge that requires engineers along with the rest of society to question their values in relation to human exploitation of nature and the continued failure of industrial development to deliver basic services like water and sanitation to the world's poorest people.

The modern engineering profession has its origins in the military. Engineers were originally responsible for the construction of roads, bridges and the production of armoury in standing armies (Davies, 1998). As the industrial revolution began in the seventeenth century, engineers were also employed to build canals and new transport routes for increased trade, as well as to oversee the design and implementation of new industrial technologies in textile mills. By the beginning of the nineteenth century, engineers who had risen from various backgrounds, including the trades and crafts as well as the educated middle class, began to form professional associations and develop standards for professional education and training. The Institution of Civil Engineers was formed in London in 1828 as the world's first professional engineering institution. The designation 'civil' engineers distinguished the work of these new engineers from their military counterparts. Over the following century, new disciplines of engineering formed as technology developed and engineering knowledge became more specialised. Mechanical, chemical and electrical engineering emerged in the nineteenth century, with electronic, environmental, software and many other disciplines forming in the twentieth century.

7.1 ENGINEERING KNOWLEDGE

Vermaas et al. (2011) in their volume in this series analyse the role of engineers in designing discrete technologies and more complex socio-technical systems. Engineers are central to the development, design, manufacture, construction, operation, maintenance and disposal of both technology and socio-technical systems. They are also involved in policy making, financing, regulating and managing technology and socio-technical systems. Engineers bring particular specialist knowledge about technologies and infrastructure to these arenas, but, more importantly, engineers bring a particular way of knowing the world. Engineering knowledge and method are the defining elements of engineering as distinct from other professions and academic disciplines. They underpin the different disciplines of engineering, and they are what engineers have in common across domains as broad as nuclear reactors, computer chips, steel works, satellites, drug manufacturing and racing cars.

Engineering knowledge stems from individual and collective experience of solving physical problems, with a specific purpose in mind. Engineers use and develop tools, techniques, and methods for solving problems more efficiently and with greater certainty. These include mathematics and scientific theory, but engineering is not merely the practical application of maths and science. Indeed, scientific knowledge is often derived from engineering problem solving. Engineering knowledge is based on constantly extending the 'state of the art,' which refers to the best available knowledge and techniques for analysing physical problems and designing solutions. Engineering knowledge must be adaptable to specific conditions of new contexts in which problems occur.

Heuristics and 'rules of thumb' are an important element of engineering knowledge (Koen, 2003). Rules of the thumb are convenient simplifications that are agreed upon by the professional community in order to solve new problems as efficiently as possible. Whilst it is important for engineers to consider the specific context and conditions of every new project or problem, it is not necessary to thoroughly analyse each situation from first principles. Nor is it necessary to be able to derive detailed explanation for why a particular tool or rule is effective, if collective experience attests to its effectiveness. Engineers are most interested in what works and how it works, without requiring a detailed scientific explanation of the physical principles underpinning the phenomena they are exploiting or seeking to control (Vermaas et al., 2011). Detailed scientific understanding may help extend the state of the art and provide insights into the nature of problems at hand, but it is not a necessary precondition for good engineering per se.

Standardisation and codification are important for stabilising and extending engineering knowledge. Based on scientific investigation and practical experience, engineering codes help stabilise rules of thumb and provide minimum standards for safe performance. Agreed through professional peer-review processes, engineering standards address methods as well as outcomes.

The relationship between engineering and the physical sciences is well established, and engineers are expected to have a good knowledge of basic scientific principles as well as a familiarity with the scientific method. Engineers are generally less familiar with the social sciences and social science methods. As a result engineers' knowledge of society is often based on personal experience, the popular media or stereotypes. Engineers use rules of thumb relating to social phenomena similar to those relating to physical phenomena. However, social rules of thumb are less likely to be subject to critical evaluation or the processes of standardisation that are important for safety and the ongoing development of the state of the art.

Engineers rarely work alone and are usually associated with large organisations, either being directly employed by large industrial corporations, the government, military and consulting firms, or subcontracting to them. Working collectively helps engineers share experience and knowledge, and provides checks on individual work to ensure safety. Team work also allows for specialisation within engineering projects, so that individuals bring detailed understanding of 'state of the art' knowledge across different domains.

Engineers' association with large projects and organisations is also one of the core characteristics of the profession and a significant challenge to the capacity of the profession to respond to the challenges of sustainable development (Davies, 1998, Riley, 2008). As technologies and systems for sustainability operate across different scales and address the needs and interests of users, the environment and the poor, it may become necessary for the profession to develop new models of professional formation, expertise and service. Incorporating local knowledge into engineering decisions, providing engineering expertise to support community initiatives for sustainability, and designing systems that engage with everyday life of users to reduce resources consumption are significant challenges to the conventional model of engineers associated with large scale developments and organisations (Baillie, 2006).

Engineers' tendency to work in teams and as part of large organisations, and the importance of standardisation and codification of engineering work, means that their design work is rarely recognised by society in the same way that the work of product and architectural designer is acknowledged. Whilst historical figures are recognised within and beyond engineering, the engineering profession do not produce celebrity figures in the same way that architecture or other professions do. Engineering attention to safety, team work and fulfilling the needs of the client tends to mitigate against the rise of particular personalities. Engineering design, though highly creative and innovative, is often invisible to users of technologies and systems. Engineers work to create stable black-boxes. Engineering design most commonly only becomes visible when systems fail, and good engineering is often by its nature unnoticed by everyday users and the public.

7.2 TECHNOLOGY AND VALUES

Debates about technology and values often concern the extent to which technology determines human actions and social outcomes. Andrew Feenburg (1999) has identified two key dichotomies in ways of thinking about technology. The first is the dichotomy between technology as value neutral or value laden, and the second is between technology as human controlled or autonomous. Presented as a matrix, these lead to four distinct characterisations of the nature of technology (Table 7.1).

Most engineering approaches to technology can be characterised as instrumentalist. Engineers characteristically maintain that technology itself is value neutral, and that humans express values through how they use technology. Humans are in control of technology and technological development. Technological progress is humanly determined, and whether or not it leads to positive of negative outcomes for society or the environment depends on how technologies are used, not the

Table 7.1: Theories of Technology (Feenburg, 1999, p. 9)

Technology is:	Autonomous	Humanly Controlled
Neutral (complete separation of means and ends)	Determinism (e.g., traditional Marxism)	Instrumentalism (liberal faith in progress)
Value-laden (means form a way of life that includes ends)	Substantivism (means and ends linked in systems)	Critical Theory (choice of alternative means-ends systems)

nature of the technologies themselves. A very crude simplification of the instrumentalist view of technology is the slogan 'guns don't kill people, people do.'

In addressing the moral and social as well as technical elements of sustainability, engineering can learn from more critical approaches to technology and socio-technical systems. As actor-network theory shows, technologies are both shaped by and determine social relationships and human behaviours. Technologies have particular assumptions about the world 'baked-in' to them, and as such perpetuate the worldviews that formed those assumptions. Centralised water infrastructure systems were based on assumptions of endless supplies of water from the environment, resulting in cultural practices that demonstrate a very low value of water and aquatic ecosystems that may be harmed as a result of over abstraction. Technologies such as automatic washing machines represent values of cleanliness and convenience, but they do not necessarily value water as a scarce resource.

Critical theory presents technology as value laden but humanly controlled. This means that although technology embodies certain human values, humans control technology and technological development through design, regulation and operation (Feenburg, 1999). Throughout the modern industrial age, when environmental values were not considered important, technologies were developed that reflected values of economic growth and higher standards of living. As values change, it is possible for engineers and others to become engaged designing, building and operating technological systems that embody the values of sustainability. These values include preserving natural systems and resources for their own sake, as well as for future generations, and addressing the needs of the world's poor through appropriate development.

There are different views as to the role of values in design. Friedman and Kahn (2003) identify three different worldviews. An 'embodied' view of design holds that designers inscribe particular values and intentions into the technology. The 'exogenous' view is that societal forces shape how technology is used, consistent with an instrumentalist view of technology. The 'interactional' conception of design is that design supports some values and hinders others, but that the user has ultimate control of the technology.

The interactional view of design is broadly consistent with an actor-network approach which shows how networks of humans and non-humans are stabilised but can also unravel. Technologies script certain behaviours that reflect particular values, but these depend on meeting the interests of users (Vermaas et al., 2011). Users are free to re-script technologies with their own values. For example, continuous clean water has been provided by engineers to households in the interest of public health, but users in networks of appliance, plumbers and manufacturers have re-scripted water infrastructure as a source of pleasure and cleanliness.

7.3 ENGINEERING VALUES

The extent to which values influence engineering work depends on underlying assumptions about the nature of technology and design. An instrumentalist view of technology and an exogenous perspective on design absolve engineers from any direct responsibility for the uses of technology and social or ecological consequences. Even from more critical perspectives on technology and design, the engineer can still be seen as a servant of client values. Alternatively, as technical experts, engineers can be seen as gate keepers of technology, as central actors in technological society who allow the material expression and stabilisation of particular values and the suppression of others. Engineers can also be thought of as mediators between technology and society, facilitating the interactions between values and objects that shape technology.

Engineers as servants simply carry out the instructions of clients, and they have no control over, hence no responsibility for the outcomes of their work. Clients' demands may be constrained or shaped by wider social and political values, either directly through legislative controls, or indirectly through social norms and aspirations, but the practice of engineering is separate to these processes. Engineers' primary responsibility is to their client, who bears responsibility for the outcomes of technology within the wider context of social and political norms and regulations. Clients can be the corporate employers of engineers, governments, or private individuals. The engineer has no power to influence or change the rationale or outcomes of technology but merely implement the demands of more powerful clients.

Engineers as gatekeepers hold ultimate responsibility for the outcomes of their work. Heroic accounts of successful engineering projects such as the construction of London's sewers, the Hoover Dam, space exploration, and the computer revolution, put engineers centre stage. In these instances, engineers are ultimately responsible for the positive social outcomes of technological progress. On the other hand, engineers must also carry responsibility for failures of technology and technical systems. Engineers have been held responsible for spectacular technical failures such as the space shuttle Challenger disaster and the Bhopal chemical gas catastrophe. Although engineers may be acting in the interests of their clients, their primary responsibility is to the health and safety of the public, and as gatekeepers of technology, they ultimately determine the values that can be expressed through design, development and operation of technology.

Engineers as mediators are critical actors arranging networks of humans and non-humans into technologies and socio-technical systems. Engineers work to mediate the interests of different humans within the realm of physical possibilities. Engineers cannot design technologies that are physically impossible but are constantly expanding the realm of the possible through their intimate knowledge of the non-human actors and the state-of-the-art that they work with. Aligning the non-human actors with human interests is a primary task for engineers, and as actors themselves in the network, they have significant capacity for negotiating these relationships. However, engineers' agency is constrained by what is physically possible, in terms of the limits of non-human actors, and what is socially, politically and economically achievable, in terms of maintaining the interests of primary human actors.

Engineering codes of conduct typically recognise engineers as servants, gatekeepers and mediators simultaneously. The gatekeeper role of engineers is evident in their primary ethical responsibility to ensure public safety. The servant role is demonstrated through their duty to act in the best interests of the client. The mediator role is increasingly important as codes of conduct have been expanded to include a duty to work to achieve sustainable development.

7.4 MEDIATING SUSTAINABILITY

Engineers as mediators have the potential to reconfigure relationships between humans and non-humans to ensure the long term viability of natural resources and systems for future generations, and to acknowledge the intrinsic value of non-human nature. Engineers as mediators can recast dualistic relationships of domination of culture over nature, bringing the interests of non-human natural actors to the networks of socio-technical systems. However, this requires significant reform of the role of engineers in society and the economy and new models of engineering practice. New techniques for engineering design have been developed that account for the role of values in technology development and allow for greater involvement of the public in technical decision making. These include value-sensitive design and constructive technology assessment.

Value-sensitive design methods have been specifically developed in software engineering but have wider applicability to sustainability engineering. Friedman and Kahn (2003) outline three elements of value-sensitive design methodology: conceptual, empirical and technical investigations. Conceptual investigation involves designers asking questions about what stakeholders are directly or indirectly affected by the design, what values are at stake, and what are the likely tradeoffs between values. Empirical investigations involve engineers drawing on social science methodologies to move beyond conceptual questions to gather data regarding the actual interests and values of those implicated in the technology under development. Methods for gathering social data include surveys, interviews and focus groups. Empirical data about stakeholder values and interests can be considered alongside technical data in the design of the technology. Technical investigations focus on how existing technologies support or suppress the expression of particular values, and, in turn, how new technologies can be consciously developed with particular values in mind. The most significant contribution of value sensitive design is to acknowledge that technologies embody particular values and to bring this to the consciousness of designers. This allows for greater ethical deliberation by engineers as they consider their role in configuring particular arrangements between technology, society and nature. Engineers may not always have the power to promote the values of sustainability within a design project, but these methods allow them to be more cognizant of their limits as well as the opportunities to achieve change.

Constructive Technology Assessment has developed in the Netherlands, Denmark and elsewhere in Europe (Rip et al., 1995). Technology Assessment originated in the 1970s as European governments became concerned about the impacts of new technologies on society and the environment. Methods of evaluating new technologies as input to regulation were developed, including citizen panels, socio-technical experiments and expert analysis. Citizen panels take randomly chosen or self-selected members of the public, provide them with detailed information about new technologies and access to technical experts, and ask them to provide an assessment of the likely impacts and acceptability of new specific new technologies. Socio-technical experiments involve small scale trials of technology in use. Assessment of new technologies provided government with guidance in developing new technology policies and regulations but was based on essentially stabilised technologies, late in the lifecycle of development.

Constructive Technology Assessment extends the principles and techniques of Technology Assessment upstream, to influence the design of new technologies, rather than simply assessing the impacts of more-or-less finalised products. This allows for a wider range of social and policy goals to be incorporated into new technologies, and it helps to dismantle the traditional divide between technological development and social impacts. Constructive Technology Assessment allows engineers to obtain feedback on their work early in the stage of development, so that they are able to respond to concerns about impacts and incorporate aspirations that they may not have considered independently. Constructive Technology Assessment explicitly acknowledges the hybrid, socio-technical nature of most technology development projects, and it provides opportunities to consider and direct technological development to maximise positive outcomes and minimise harm.

These design tools break through the separation of technology and society which has characterised the development of modern industrial society. Conventionally, engineers are isolated from society, designing and managing technologies according to the requirements of clients, corporations and governments. This model of technological progress allowed for the proliferation of new technologies and delivered significant advances in the material standards of living of millions of people. However, it also created lifestyles that required the consumption of resources at unsustainable rates, industrial systems that have polluted the environment and destroyed ecosystems, and failed to deliver even the most basic benefits of development to the world's poorest people.

7.5 SUSTAINABLE ENGINEERING

Sustainable development acknowledges the need to reconsider the dominant model of modern industrial development to address social, ecological and environmental considerations simultaneously. Sustainable development is a hybrid concept, which is neither technical nor social but bridges across these distinctions. Engineering contributions to sustainable development to date have been restricted to providing technological solutions to environmental problems and have struggled to address social dimensions, and the relationships between technology, environment and society.

Philosophers of technology, sociologists and anthropologists have argued that technology is value laden. The major infrastructure systems that underpin modern societies, including transport, energy, water and waste, embody assumptions that natural resources are endless, that supply can continually be extended to meet demand, that the environment can absorb pollutants, and that natural systems have no value other than for human use. New technologies and infrastructure systems as a starting point need to question these assumptions and values. As engineering codes of conduct now explicitly refer to engineers' ethical obligations to society, the environment and the goals of sustainable development, new technologies and systems should be developed that embody alternate values.

Engineers have significant influence in the design and management of technological systems, but they work in economic and political contexts in which economic growth, profit and ever increasing material standards of living predominate. Engineers alone will not be able to deliver sustainable technology. The ecological crisis will not be solved simply by engineers producing more efficient, less polluting technologies. However, as mediators between technology, society and nature, engineers are uniquely positioned to present alternatives to dominant models of development and to facilitate the emergence of more sustainable patterns of consumption.