Ethics and Sustainability in Engineering

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Abstract
The numerous examples of themes, descriptions of sustainability in many complex shapes and sizes some ranging from strategy, framework, phrases, concepts, indexes, indictors, weak, strong, externality, internally and criterion are scattered throughout the scientific and scholarly literature. Hence, presenting an immense diversity of opinion, with confusion to its literal implementation. "Sustainability" as function of transdisciplinary variables which are underlined in three common themes, social, economic and ecological also known as bottom triple line. Many questions are raised than answers, what is sustainability, is it a utopian state or pseudo ideal process? Is it a strategy, where do the complex issues of sustainability leave us engineers? The objective of this paper is to define the bounds of ethics in engineering sustainability and to investigate its dimensions in order to quantify sustainability.

Key Words: Sustainability, ethics, morals, industrialization, Malthusian, cornucopian.

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1. Challenges

Current global environmental concerns, mainly climate change, global warming, raises many obstacles such as food supply, and energy shortages, i.e. the nuclear power generation debate. On the other hand the decline of the Organisation for Economic Co-operation and Development (OECD) chemical/manufacturing industries the shift in manufacturing to offshore countries mainly developing countries in particular Gulf states, India and China hence altering the distribution of wealth from the traditional Western developed countries to developing countries. The above mentioned are part of the competing sustainability challenges engineers and will inevitably engage during professional practice and it also raises questions concerning the ground rules of engineer's accountability and contribution to society. Are engineers motivated by profit margins, technical advancement or is it our responsibility to uphold sustainability in our work given the financial crisis of 2008? Hence, it is worth wondering whether the world is on course for further dramatic social and economic change and whether such changes as they do take place can be steered to benefit all of human kind i.e. sustainability and growth. Principles, morals and values are positioned within the context of human conviction; the industrial revolution affected our life styles and our interaction with the environment, economic developments. Managing sustainability in engineering involves incorporating the needs of users in participation, community involvement, transparency of decisions, and consideration of all affected stakeholders. Obtaining consensus at different stages of the process is a challenging; in fact it is still relatively unknown at what stage the broader stakeholders should be engaged in decision-making and how they should be engaged. However, the fact remains that building support for an initiative is critical if it is to succeed in changing attitudes toward sustainability and will likely avoid expensive litigation. However the questions on environmental depletion particularly in the third world remain unrequited. The engineering discipline has not yet founded the framework to understand the links between the engineering sustainability and ethics. Clarification will station realization how innovation and sustainable development may influence one other. The paper begins by exploring global warming linked with the antecedent of civilisation followed by the relationships between engineers, technology and society and finally presenting a conclusion on engineering and sustainability. The main aim is to highlight the silo mentality that exists between disciplines when it comes to sustainability.

2. Global Warming

Global warming, climate change and energy are of greater than ever concern in the 21st century as it is more widely realised that the planet Earth does not provide an infinite capacity for absorbing human industrialization that began in the middle of the 18th century[1,2,3,4]. Yet, industrialization is regarded as the engine of economic growth [5,6]. Similarly, industrialization is linked to environmental degradation [7,8,9,10,11]. In the period since the early 1960s this has tended to increase over time in the wealthy countries of the Western industrialized world, whilst typically falling in the poorer developing nations. The situation with demographic growth has been quite different, for example, with almost stable populations in many affluent countries of Northern Europe, whereas rapid population growth has been observed in contrast in many parts of the developing world including Africa, continental Asia, and Central and South America[12]. The existence of economic growth and environmental degradation is explained by the Environmental Kuznets Curve (EKC), where environmental degradation and per capita income growth exhibit an inverted U-shaped relationship shown in Figure 1. Hence if we weave industrialization, economic growth and sustainability together, it forms a teleological account, as economic growth is a necessity to sustain the exponential population growth. Therefore whether a Malthusian, Cornucopian, sceptic or advocate of climate change, economic growth is required, not so much for ourselves here in the Western world, but because of the needs of that other half of the world population in developing countries, still growing rapidly, which is entitled to their share of wealth and happiness[13].

3. Civilization and Environment

In search of antecedent evidence we draw on the history of civilization as it abounds with examples. [14,15,16,17,18] report on soil erosion that led the fall of civilisations from the Akkadian Empire of Mesopotamia, Babylonia, and Assyria to Rome. [19,20,21,21,23] blamed environmental mismanagement for the fall of the Mayan civilisation, Sumeria, ancient Egypt, the Ur Dynasty and the Abbasid Caliphate. [24] reported on the Mediterranean regions of ancient Greek civilisations that had seen many episodes of ecological destruction directly caused by human action, sometimes irreversibly. A more recent example, carbon dioxide, CO_2 a by-product of industrialization, is also considered one of the main contributors in the human-induced global warming that is accelerated by the burning of fossil fuels and deforestation (i.e. the more we burn the more greenhouse gases are produced where the planet's natural variation alone is and was incapable of recovering).

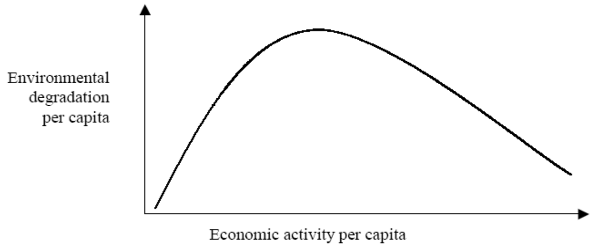

Figure 1: The Environmental Kuznets Curve (EKC)

Reviewing some of the ancient catastrophes, the common occurring theme observed was societies had perished after destroying their means of support, irreversible environmental changes. In other words, environmental-related issues were contributing factors to the demise. These factors were partly the ramifications of engineering or technology. In a nutshell, poor irrigation, which was an engineering task, actually led to the fall of the ancient Mesopotamian civilisation. Therefore, there are some opportunities to learn from history. However, according to [20] history is not on our side. Whilst using history as a benchmark, we recognise notable differences exist between ancient and modern states, and no society's collapse can be attributed solely to environmental change. However, efficiency in resource use and management is the critical success factor. The question of energy, where it comes from, what it costs, its environmental footprint, how we use it, and how long current sources will last, needs to be answered. Similarly, engineering efficiency is vital to society's survival as efficiency is the total opposite of squandering. Thus surrounded by this realm of thinking we deduce the importance of "energy efficiency" as a core element of the sustainability mission, since global warming and climate change issues are nowadays typically coupled with the concept of sustainability. For this reason, sustainability cannot be addressed separately from engineering efficiency, which is generally acknowledged as the result of a balance among the three elements: economic, environmental, and societal [25]. These spheres form the contextual background for engineers, highlighting the spheres of influence as in Figure **2** that is, society, technology and efficiency, in an engineering discussion towards sustainability. The following section presents a discussion on technology and society as it represents the linkages between them and sustainability to illustrate its importance for engineers in achieving sustainability.

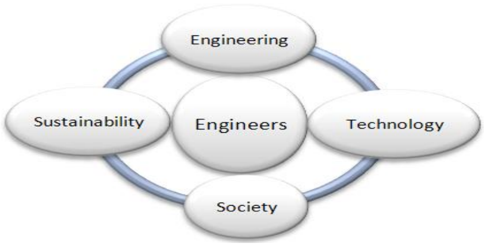

Figure 2: Spheres of influence

4. Engineers, Technology and Society

We live in a world captured, uprooted and transformed by the titanic economic and techno-scientific process [26]. According to [27], two-thirds of the real wealth created annually in the United States comes from manufacturing. However, no official statistics exist which can answer what specific contribution engineering makes to the Australian economy since engineers are spread across an extremely diverse number of industry sectors and it is impossible to segregate their contribution to productivity from the contributions made by other parts [28]. According to Johnston [29] engineers have key roles in wealth creation and in innovation. Therefore, engineers are categorical wealth creators, whereas other sectors redistribute wealth. Hence, to systematically address sustainability, we need to address technology energy efficiency inclusively. Engineers are creators of technology[30], through the application of scientific principles design and construction essentially defines engineering. Similarly technology is directly related to economics.

In a global historical context, [31] suggested four periods of evolution in human population growth, the first related to the development of local agriculture (8000 BC), the second related to global agriculture (AD 1750), the third related to public health (1950) and the fourth related to fertility (1970). But it is information technology that defines this special period. Whether IT, digital age, digital society or a global village, these are all terms that define a reliance on energy. Similarly, according to [32, 33, 34, 35, 36,] whether the focus is technology, the economy, or society at large, it is widely accepted that technology will have profound effects on natural resources. Engineering has been central to the great economic growth that has characterised the rise of industrial capitalism and as we move into a knowledge-based economy it remains a fundamental element [28].The reason is that information technology lies at the root of productivity and economic growth [37]. Economic developments in the first decade of the 21st century emphasize the essence of information technology and digital society in the expansion of knowledge [38,39,40].However, a digital society implies dependence on networked ICT's, with more people using the internet, cell phones, digital video, digital music, and PC's, and so forth. Therefore, a digital society implies reliance on electricity in supporting 21st century socioeconomic development [41]. But electricity, by tradition, poses reliance on natural resources.

According to [42] technology develops as a response to a perceived problem, need, or desire. The waves shown in Figure 3 illustrate the progression of technology along with time simultaneously with the maturing civil society. Development is often described in terms of the successive advances in technology. For example, the steam age, the industrial age, and the information technology age all refer to different historical periods. We now live in a world that is highly reliant upon technology for food, employment and economic prosperity. Very often several solutions are available to address a given situation. Being able to select the most appropriate technology initially can reduce the potentially disastrous social, economic and environmental impacts that an inappropriate choice may have in the long term. In the 1930s the German economist, Schumpeter, noted that technological innovations are not evenly distributed over time or across industry, but appear in periodic clusters. These techno-economic revolutions depend on clusters of mutually supportive technological innovations being accompanied by social innovations in areas ranging from organisation and management to taxation and employment law [43].

5. Engineering and sustainability

Society is becoming even more dependent on engineering and technology [44]. In the words of [45], engineering, as an element of technology as a social process, is actually changing the world. Technology is the process by which humans modify nature to meet their needs and wants [46]. Technology is essential to the human condition. Our human species is now totally dependent upon it. Without technology, we would not be able to sustain the present human population on this planet. Moreover, without technology, the human population could never even have grown to anything near its current level. Put simply, every technology has efficiency. In the decades ahead, technology will be called upon to feed a growing world population with minimum impact on the integrity of soil, water, forests, and other resources [47]. Therefore technology is intertwined with society's progress and untimely natural resource consumption. Finally, technologies "evolve" to solve the problems as perceived by various relevant social groups. Therefore, contemporary society, science and technology are inseparable. This is validated by the Social Construction of Technology (SCOT) Studies [48,49,50,51,52,53,54,55].

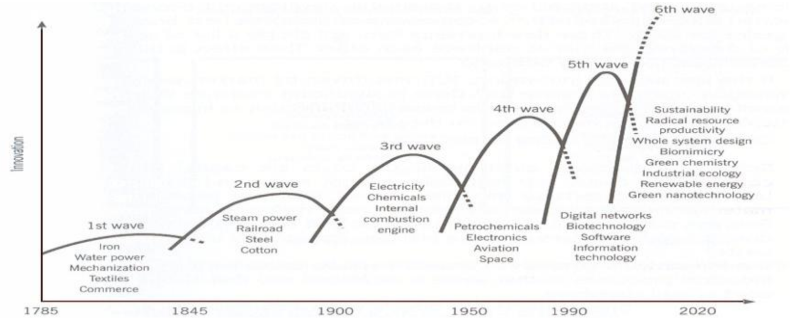

Figure 3: Waves of innovation (Hargroves, 2005)

- The major sources of environmental pressures normally associated with the different components of a technology are energy, materials, labour-skills, infrastructure, waste and products. The main pathways by which a technology interacts with its surroundings can normally be divided into the following categories: the material, labour and energy resources used by the technology, the wastes and hazardous products released into the environment, and the impacts of the supporting infrastructure and services. The environmental consequences of a technology will vary with both the characteristics of the pressures. The critique of the technology root of sustainability originated in 1960s and 1970s [56]. This theory was advanced by [57] however [58] suggested that the root of sustainability in a broad sense has originated from six separate strains, but we do not intend to describe each of these, only technology. Instead as practising engineers our interests in society are constructed by our professional relationship with sustainability,
- As a practicing engineer, I often hear colleagues question their morality have we done enough as in our work place to prevent pollution etc..!
- How do we contribute towards sustainability? Meaning, is it an engineer's responsibility? Or is it some else's job?

- What is sustainability? Definitions of sustainability abound, is it the most oft cited [59]
- What are the imperatives for sustainability? According to [60], [61], [62], and [63] the role of engineers in society is changing, placing new pressures and demands on engineering education.
- What are the key drivers of change towards sustainability principles? The role of engineering education in sustainability movement is a growth area, literature is rich with citation [64]. Most citations refer to an approach of eliminating stereotypical notions of engineers about sustainability [65]. The new broader roles for engineers occur in emerging engineering disciplines "sustainability," innovation, and entrepreneurship[66], in interdisciplinary activity, and consequently in the protection of health, safety and the environment. According to [85] engineering graduates are needed to serve society, not only in the traditional technical capacities which they need to master well, but increasingly in non-technical leadership capacities.

Conclusion

Principles, morals and values are positioned within the context of human conviction; the industrial revolution affected our life styles and our interaction with the environment, economic developments. Sustainability law would represent an attempt to imagine a system of laws and policies that facilitate processes, products, and patterns of behaviour which are good for the planet.Sustainability culture is the embodiment of decision making and accountability at all levels, leadership, behaviours, accountability and attitudes. Whilst economic disincentives exist we need incentives for promoting sustainability as a profit centre to eliminate the gap between what executives believe to be sustainability and what it actually is on the ground. Considering the premise of humanity as a family and natural disasters, environmental catastrophes are not limited to national boundaries; collectively these concepts draw attention to the engineer's contribution to sustainability and responds to what if anything any one individual can do on behalf of humanity. We remain optimistic that it is possible for engineers to contribute to a better world through ethical behaviour in the respective professions.

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