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SUSTAINABILITY, DESIGN AND ENGINEERING VALUES

Paul Martin WINKELMAN
University of British Columbia, Canada

ABSTRACT
Sustainability issues are slowly being integrated into the design process. What is frequently overlooked is that the pre-existing value system of engineering may be hostile to sustainability principles. To explore this value system, the engineer is presented as a wearer of many hats (e.g., that of a soldier or dépanneur) who hypothetically develops a sustainable solution involving the installation of latrines in Rajasthan in India. The question is then whether this engineer is able to foresee the social issue where the latrines lead to the disempowerment of women. As a soldier, the engineer models the world after hierarchies; Maslow's hierarchy of needs suggests that one can deal with the physiological and worry about the social later. As dépanneur (owner of a corner store), the engineer values convenience; the latrine, though convenient, led to increased seclusion of women at home as they had lost their reason to leave the house. These engineering values are offered as possible “constraints” on the road to re-creating engineering design more in the image of sustainability.

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Contact:
Dr. Paul Martin Winkelman
University of British Columbia
Mechanical Engineering
Vancouver
V6T 1Z4
Canada
pwinkel@mech.ubc.ca

1 INTRODUCTION

The push to include sustainability concepts and issues in engineering design is well under way. The hope is that these inclusions will lead to engineering having a greater positive impact on the so-called "Triple Bottom Line" (TBL), simultaneously addressing economic, environmental and social "needs" in ways that "traditional" engineering design did not – or could not.

Traditions are, for better or for worse, notoriously hard to change. Change, however, is essential if sustainability is to find a permanent home in engineering and engineering design. In order to do so, we need to have some understanding of what that tradition is so that we might intelligently discriminate among those features of the tradition that can remain, those that should be altered, those that are best discarded and where the tradition might be extended.

Extending or adding to the tradition appears to be the method of choice as it leaves the tradition itself relatively intact, with few feathers being ruffled, while still addressing emerging issues. One example of this approach might be the automobile: despite the carnage on the highways, the traditional automobile persisted until Ralph Nader brought to our attention that it was indeed possible to make cars safer. Safety was accomplished by adding features to the automobile: add seat belts; add head restraints, add air bags. The new, safer car looked essentially the same as the old, unsafe car and the car paradigm remained unchallenged.

This "add-on" mentality can be seen within engineering education. When ethics was added to the engineering program, it often took the form of a new required course which, if personal experience is anything to go by, were not truly integrated into the rest of the program, as older courses carried on with business as usual.

A similar trajectory can be seen with the efforts to include engineering design in the curricula. Early "attempts" were merely re-labelling: what used to be called analysis was re-presented as "design", with little thought given to the ("real"?) design which must take place in order to have something to analyse in the first place. Fortunately, design courses, with greater synthetic content, have become a more integral part of engineering programs. In some ways, however, this integration is illusionary, for design retains much of its "add-on" status, in that design is taught as a process, taking the form of a series of checklists and methods. What is lacking is a strong theoretical base. Theoretical bases are prevalent within traditional courses, normally taking the form of mathematical equations, such as $F = ma$ or $V = IR$; methods are always constructed in full view of the theory. Checklists are relatively rare (although one might argue that the variables contained within the equations are checklists in disguise). Notwithstanding methods and checklists, the weak theoretical base means that engineering design must content itself with being "second best", for it is theory that separates, borrowing the words of Charles Taylor (1996), the "contenders" from the "pretenders". Nevertheless, some promoters of engineering design would appear to be content with the "pretender" status, as they see design as being all about doing and resist any efforts to include design theory.

A similar trend can be seen within some of the recent efforts to include sustainability within engineering. Re-labelling seems commonplace. As an example, consider an "environmental engineering" textbook, edited by Mihelcic and Zimmerman (2011). The discussion of "environmental measurement" in Chapter 2 is built around some basic concepts of chemistry. So, what used to be called "chemistry" is now labelled as "sustainability" since now, for example, the concentration of pollutants is being determined. This gives a weak sense of "progress", even a sense of regress, a reminder of Dupont's old adage of "better living through chemistry" (Florman, 2013). Chapter 10 presents some calculations related to a settling tank. This looks identical to some of the material presented in a course I took in 1985, entitled, "Waste Management". At that time, there was no reference made to sustainability. Taking the form of a modified design process (see, for example, Gagnon *et al.* (2012)), sustainability risks suffering from the same theoretical impoverishment of engineering design and its accompanying loss of status.

This is not to say that these approaches are necessarily ill-conceived, for old data and techniques can be re-directed for very different purposes. I can use census data to determine how to tax people more or how to equitably distribute government funds for social programs. At the same time, if the data were originally collected for the sake of taxation, and I wish to promote social programs, the data may be skewed in ways that result in certain issues being misrepresented, predisposing me to think in certain ways and my new purpose is undermined. In the case of the new, "sustainable" engineering design, the re-labelling and re-directing of current traditions is generally aimed at environmental concerns, undermining or neglecting social issues.

This neglect of social issues within engineering is evident among many of the student projects I have been involved with over the years. One team in particular, consisting of very capable, enthusiastic students, carried out a TBL assessment of a range of potential products. They conducted user evaluations of more environmentally friendly products with those not so environmentally friendly. The extent of their social analysis was limited to presenting which product the participants of the study preferred. I was hoping for some analysis that would show how the lives of some might potentially be impacted by the students' choices and recommendations.

To help my students to think more in terms of the social issues, I provide a personal example. I live 20 kilometers from the university where I work. The reason I don't live closer is that I can't afford to buy a residence of reasonable size nearby. So, I commute by car. As I drive, I consume energy, produce pollution (including noise), contribute to traffic problems, and risk injuring or even killing people along the road. I could reduce these effects by taking public transport, but that would considerably lengthen the commute time which during the busy times of the semester, would come directly out of my sleep time. It would also make it difficult to pick up my child on time at after-school care. Although I see sustainability as a worthy cause, I resent any expectation that I take public transport or live in a tiny apartment as this would impose an unfair burden.

The idea of "unfair burden" alludes of one of the central tenets of sustainability, namely that of *equity*. Unfortunately, this issue is not generally raised in engineering circles where sustainability is discussed. In general, the engineering response has been, I believe, slow and inadequate, despite the fact that this connection between physical sustainability (*e.g.*, pollution from commuting) and equity (*e.g.*, I commute because I can't afford to live nearby but apparently others can) has been around since at least 1987, as contained in the so-called Brundtland Report:

> "Development involves a progressive transformation of economy and society. A development path that is sustainable in a physical sense could theoretically be pursued even in a rigid social and political setting. But physical sustainability cannot be secured unless development policies pay attention to such considerations as changes in access to resources and in the distribution of costs and benefits. Even the narrow notion of physical sustainability implies a concern for social equity between generations, a concern that must logically be extended to equity within each generation" (World Commission on Environment and Development, 1987, p. 41).

O'Reilly (2010) provides an illustrative example of equity issues impinging on design. She examines the effects of the installation of latrines in Rajasthan, India. These latrines are primarily targeted at women who have greater concerns of security than men and, as household managers, are more likely to improve family sanitation and hygiene and pass on good habits to the children. In addition to hygiene, latrines are also seen as being very convenient due their proximity and availability, both day and night and through all kinds of weather. This convenience was intended to aid women, who normally hold their bodily functions all day and go out after sunset to relieve themselves outdoors in the cover of darkness. However, as all the women went out at this time, this was their main opportunity to socialize; the installation of latrines brought this socialization to a halt. Rather than empowering women, latrines left women in seclusion at home, reinforcing gendered norms.

This example of the latrines demonstrates the complexities that arise in as one tries to address the "needs" where inequalities exist. My hope is that questions surrounding equity, and other social issues, will become a normal part of engineering design. I concur with Nagel, et al. (2012b) that sustainability should be the central context of sustainability, rather than an add-on. Efforts to re-orient engineering in this direction are likely to face opposition from traditional engineering. The opposition arises from a clash of *values*. One can impart a great deal of knowledge to engineering students and leave their sets of values relatively unchanged (Nagel, et al., 2012a). The problem is exasperated by the fact that values are often unspoken and very subtle. Students gravitate toward these values and tend to "organize the world to fit their expectations" (Downey, 2009, p.59)

2 OBJECTIVE

The objective is to show how seemingly "innocent" values and assumptions of engineering may serve to potentially undermine efforts to integrate sustainability within engineering design.

3 APPROACH

To show areas of mismatch between the goals of sustainability and the values of traditional engineering, I use a combination of discourse analysis, curricular designs and case studies presented in the literature, and philosophical concepts. The ideas are organized according to six "hats" which engineers might wear, each "hat" representing a role with its own set of values. Thus, as engineers switch among the various hats, their value sets shift with them. However, these value sets have a great deal in common and even as engineers change their hats, it is not difficult to recognize the engineers underneath. The value sets tend to bring certain features of the design problem to the forefront; unfortunately, the social aspects are not generally among these features which I demonstrate by revisiting O'Reilly's example of latrines in Rajasthan.

4 THE MANY HATS OF ENGINEERS

3.1 The Engineer as Scientist

Science has long been considered one of the intellectual pillars of engineering. Students entering engineering programs are expected to have a strong background in science. But why science?

Science focuses the engineers' attention on the physicality of our world. Of the sciences, physics dominates. Physics sees the world as made up of mechanisms, as objects having properties and the relationships between these objects is generally reduced to a series of forces. The "laws" of physics speak of universality, displacing notions of time and place. History and context are therefore relegated to secondary roles at best. Science greatly values objectivity, leaving little place for personal preference. Science therefore stresses mechanical cause and effect: what is, what necessarily was and what necessarily will be; science does not normally deal with what might be or what should be, as this would allow the bias of personal preference to creep in, compromising objectivity.

Science stresses the value of presentism. What matters most of all is the here and now, what is, what is real, what is verifiable. Science doesn't need to respond because, in the physical world what is simply is. How we use science may change, but, in idealized form, science itself does not change. Long term effects, particularly indirect ones, tend to be neglected. In the engineering world, presentism focuses the engineers' attention on the product and whether or not it "works". The ahistorical, decontextualized approach tells us that if it "works" here, it will work there; if it "works" now, it will work then. And when engineers say that a product "works", they generally refer to the physical operation of the product (I'm taking a mechanical engineering bias here).

Presentism also means that science doesn't respond, for it is descriptive, that fly on the wall that observes and listens to the here and now but does not interfere. To respond would change the very thing being observed, leading to a changeable future and a switch from the descriptive to the normative. As engineers *apply* science, engineers *do* respond for observation alone is insufficient. That response, however, tends to be restricted to the physicality of what is being responded to; if engineers venture too far in their response, they deviate from the scientific ideal and are liable to suffer a loss of credibility.

Not surprisingly, the push for sustainability has led to the creation of "sustainability science". Gagnon *et al.* (2012), for example, speak of "field of sustainability science" (p. 50) as a means of improving the design process and identify "three key issues emerging" (p. 60) from this science, namely, causal reasoning (vs an *ad hoc* selection of indicators), lack of predictability and the need for "radically" different solutions. It is not clear, however, what falls under this umbrella of sustainability science and whether something beyond science might be needed to address the problems engineers must face. So, we are left wondering how sustainability science is different from the (engineering) sciences which preceded it. Is it "radically" different? or basically the same but more of it?

As a possible answer to this question, consider a new course "Applied Sustainability and Public Health in Civil Engineering Design" (Filion, 2010). The prerequisites for this third year course are listed as "Environmental Engineering, Engineering Economics, Applied Mathematics, Fluid Mechanics, Hydraulics, and Engineering Materials" (p. 199). With the possible exception of "Environmental Engineering", the prerequisites very much resemble a list of traditional engineering courses; none deal with social issues. Presumably, the "Public Health" aspect of the course is intended to address social concerns and the accompanying background material either comes from "Environmental Engineering" (e.g., pollution?), or is covered in the course itself.

Given, therefore, this value set, to what extent might engineers be equipped to deal with the social issues arising from the installation of latrines in Rajasthan? The physicality of the latrine (*e.g.*, its chemistry, material, size, configuration, airflow, etc.) suggests that it should "work" just fine. Though outdated, they do work in, say, Canada, so they should work in India. And, physically, when it comes to latrine usage, Indians are pretty much the same as Canadians. If this is the "toolkit" engineers are expected to work out of, no amount of testing in Canada will ever reveal the problems that surfaced in India. Although Indians may be *physically* similar, they are *culturally* different, at least in this part of India. Universality is not appropriate as history *does* matter and context *does* matter. If projects such as these are to meet the needs or desires of those involved, the response of engineers must go well beyond the physical boundaries of the product.

3.2 The Engineer as Mathematician

Along with science, mathematics is one of the intellectual pillars of engineering and dominates much of engineering education (Downey, 2009). Mathematics and science never seem to be very far away from one another in engineering and mathematics shares many of the values of science. Mathematics is seen as universal and timeless. This affords a great sense of value-neutrality. Mathematics also focuses the engineer's attention on that which is measurable or quantifiable. Measurement allows for the assignment of properties to objects and a series of measurement allows for the measurement of change, leading to the power of prediction. There seems to be this unwritten belief or principle in engineering that we can only claim to truly understand something if we can mathematize it.

The ever-presence of mathematics in engineering predisposes engineers to favour the quantitative over the qualitative. This way of thinking is carried over to sustainable design. As part of an interview with a team developing a sustainable automobile, Van Gorp (2006) records one designer as saying, "I prefer to work with things that can be measured and solved" (p. 122). This bias suggests that what is being measured is not necessarily a good indicator of what one hopes to understand and questions arise concerning the value-neutrality of mathematics. Even if we could somehow prove that mathematics itself is value-neutral, the very decision to *use* mathematics is value-laden. Then there is, of course, the way we use it to make our model. We can only use mathematics once we assign meaning to it (another fallout from the "application" process of engineering). What van Gorp's car designer chose to measure is energy, for he states: "I usually work with energy because I know how to deal with that" (p. 122). This designer cannot claim to be measuring energy because it's important; rather, energy becomes important because it can be subjected to measurement – something which can hardly be viewed as "objective".

The measuring mindset, in the case of latrines, might lead engineers to determine the success of the installation with respect to hygiene. One could measure the bacterial count on, say, the hands of those in the household before and after the installation of the latrine. Beyond hygiene, one might measure the amount of time saved by not having to go elsewhere to do one's business. But how would one measure the level of disempowerment that the women of Rajasthan have experienced? What mathematical model might shed some light on the issue? Can change (greater empowerment) be measured with mathematics?

3.3 The Engineer as Soldier

The military history of engineering is well documented. One of the more visible vestiges of this past is perhaps the existence of "civil" engineering, originally created to bring engineering solutions to non-military problems. Another vestige is the disproportionately low number of women entering the profession. Within engineering education, the military roots manifest themselves through the "ordeal": students are given work beyond their ability, they receive low grades and spend endless hours on their studies (O'Neal, 1994). The "ordeal", originally designed to humiliate and break down young recruits to prepare then for reformation as obedient soldiers, is recast, in keeping with the ahistorical mindset of engineering, as the timeless virtues of hard work and perseverance.

As a kind of soldier, engineers are imparted a sense of duty. Within engineering design, we prefer to speak of "needs" rather than "desires". As "needs", engineers can respond as dutiful soldiers for failure to act would call their ethics into question. As "desires", their ethics may be called into question if they *do* act, placing a heavier ethical burden on engineers. "Needs", therefore, reduces the level of responsibility, simultaneously giving more of an objective "feel".

The military is built on a hierarchical structure. Authority and decision-making increases as one moves "up" the hierarchy, with these decisions being carried out and supported by those at the "lower" levels. A hierarchy is often thought of as a pyramid, with relatively few at the top, and many at the bottom. Those working within the hierarchy therefore develop a strong sense of the establishment and often respect and identify with it. However, due to the strong power differential inherent within the structure, people prefer to spend most of their time interacting with those at the same level, with only limited interaction between levels (similar to Lane's (2006) level hierarchy).

Hierarchies are common in engineering circles. Take, for example, authority. The "ordeal" nature of engineering education and the need to obtain that single, "right" answer imparts a strong sense of of inadequacy in students and submission to authority. A number of years ago, conducting my own case studies, an engineer talked about an engineering course he had taken where one "dare not ask a question". For many students, textbooks contain the final word and students sometimes blindly apply techniques and methods inappropriate for the problems at hand.

Hierarchies have also found a ready home in engineering design. One of the contributing factors was perhaps the work of Herbert Simon who saw hierarchies as allowing the solving of complex problems through decomposition (moving "down" the hierarchy) followed by reassembly (moving "up": the hierarchy) (see, for instance, Lane (2006) for a critique of some of Simon's work). Engineering design is seen as a problem-solving activity, with complex problems, so Simon's approach seems like a logical fit. One of the main concerns of this approach is that assemblies may behave in ways that cannot be determined ahead of time from the components ("emergent properties").

If the product is viewed as a hierarchy, then the engineering design team which produces the product may take on the same stratified structure. Thus, individual team members may end up confining themselves and their responsibilities to a single layer. This same structured thinking is then transferred to the perceived user of the product. Maslow's hierarchy of needs (not "desires") therefore seems like a "natural" fit. Working within a single layer, and having a preference for the physical, engineers will likely find themselves working at the lower levels of Maslow's hierarchy, *e.g.*, the physiological. Furthermore, "needs" would be addressed in sequential order, meaning that social needs will not be addressed until the physiological needs are taken care of.

Many of these same modes of thinking have been carried over to sustainable design. Consider, once again, authority. Gagnon *et al.* (2010), describe a "Typical Relationship" of the "Legal System" as "Respect of regulations, codes, standards, etc., and interactions with organisations responsible for their enforcement" (p. 62). We can perhaps contrast this with one of the comments of van Gorp's (2006) designers: "You have to challenge regulations; regulations do tend to lag behind" (p. 122). If engineers are striving to produce sustainable products, to what extent, then, should regulations demand their respect? Those engineers who generally trust and submit to authority may hold the view that only by violating the regulations do designs become non-sustainable. But this would seem untenable as it suggests that all engineers who have produced "unsustainable" products have acted unethically. It therefore stands to reason that at least some regulations need to be challenged, and to challenge a regulation is to challenge the authority which produced it. Those averse to challenging authority may therefore find themselves unable to make the necessary changes sustainability demands.

Hierarchical structures are also used as parts of models in sustainable design. Gagnon (2010), for instance, speaks of "analytic hierarchy procedure" (p. 58) as one of the tools for the sustainable design process. Van Gorp (2006) examines how sustainability is addressed with respect to regulative frameworks using Vincenti's "design types" (normal and radical) and "design hierarchies" (conceptual to more detailed design). Hasna (2010) uses "Hierarchical Holographic Modelling" for the purposes of risk management within the broader framework of the social, economic, ecological, technological and time. The use of hierarchies is not necessarily bad, but engineers must guard against using hierarchies indiscriminately and employing them where they are not appropriate.

The pyramid model of hierarchies also implies centralization. This results in a kind of sameness or conformity, as all those within the hierarchy ultimately look to the same authority for approval. Soldiers wear a "uniform", with "uni" referring to a sense of one-ness. Soldiers are expected to act as a single unit with a single purpose and so dissension is strongly discouraged. Centralization is thus about power and resists the distribution of that power. The acquisition of power is seen as a good thing, so movement up the pyramid (promotion) is deemed desirable.

Within engineering, centralization takes many forms. Methods, techniques and checklists seek to centralize ideas and theories to a few or a single location and can thus expedite processes, such as design. The result of that process, namely the product, also embodies centralization. The best example of this is probably the computer. Not too long ago, the television, telephone, phonograph, radio, and typewriter were all quite separate technologies. These have all coalesced into the computer. Centralization creates vulnerabilities. If my television fails, that's not a great cause for concern. If my computer fails, however, that can cause a major disruption to my day. Vulnerabilities, and hence centralization, run counter to the stability that sustainability aims to create. "Good city management" (World Commission on Environment and Development, 1987, p. 41), for example, "requires decentralization of funds, political power, and personnel" (p. 22). Unfortunately, the drive for high-tech, high efficiency systems counters many decentralized solutions. Consider a small solar system for generating electricity. At first glance, this constitutes a decentralization of electricity generation. On the other hand, if replacement parts or service personnel must come from a single source in some major city far away, the small isolated system is still effectively centralized.

The military mindset can potentially have a significant effect on how engineers might address the sanitation problem in Rajasthan. The latrine would be seen as a need, not a desire, so engineers would likely spend little time mulling over the ethics of the project. The latrine addresses a physiological need and engineers would be content to stay at this single level; addressing "higher" (*e.g.,* social) needs would seem unnecessary because, as a hierarchy, Maslow's model suggests that lower level needs must be met first. Should some engineers venture to explore the history and context of Rajasthan, they may come to understand the gender inequalities which exist. This may not necessarily raise too many eyebrows, as the engineers themselves work in a male-dominated profession. If it is an issue, then the engineers will likely find themselves in the uncomfortable position of questioning the establishment and challenging the authorities.

3.4 The Engineer as Economist

Economics is a good candidate for forming the third pillar of engineering, as is draws on mathematical constructs and agrees closely with the scientific mindset. Indeed, much of the rhetoric which surrounds science can be found within economics. For example, Weinberg (2003) writes: "On the Right, capitalism is conceived as eternal and unchanging, as part of human nature. Clearly, then, capitalism has no history. In this view, capitalism did not develop, it was created whole. Since it is eternal, it neither ages nor decays. Criticism of capitalism is blasphemy, and heretics are banished. Gifted devotees are venerated and awarded great wealth. The business press of the United States is largely devoted to celebrations of capitalism, certainly not to a critical history of its origin and development" (p. 10).

As engineers are steeped in the tradition of science, presenting economics in the form of capitalism is an easy sell. Gagnon (2010), quoting Ashley *et al.* (2008) points out that "conventional engineering is concerned with a 'relatively narrow set of economic and technical criteria...'" (p. 54). Engineering rhetoric often refers to "economies of scale", attesting to the belief that considerable savings can be realized when products are mass-produced. Mass production necessarily leads to sameness which further implies that centralization, the giver of sameness, is a good thing.

Upon moving from the conventional to the sustainable, we find that economics continues to lead the way. In the syllabus of the "Applied Sustainability" course offered by Filion (2010), it is stated that "our global economy is such that engineering design decisions made in one part of the world can have far-reaching environmental consequences in other far-flung parts of the world" (p. 200). Thus, economics comes first, and other issues, such as environmental, come later. Then, take, for example, the term "Triple Bottom Line": the "bottom line" refers to the last line in the accounting book that is either positive (profit) or negative (financial loss). There is one, single measure (money) which determines the success or failure of the enterprise. Consequently, anything that cannot be converted to this measurement scheme, cannot be entered in the books and therefore does not exist. Once again the quantitative is valued over the qualitative. If environmental and social issues, too, have a "bottom line", then the analysis of these two issues should be based on economic models. Should we therefore strive to develop a single measuring scheme for all things environmental or all things social? Do such measures exist?

In terms of environmental, the answer would appear to be yes. Investigating a design team developing a sustainable automobile, Van Gorp (2006) states that the "design team ... only considered energy use during the lifecycle of the car as a measure for its sustainability" (p. 122). In assessing sustainability in the U.K., Gasparatos et al. (2009) use a thermodynamic approach which relies heavily on energy as an indicator.

Returning to Rajasthan, the economics approach would seek to measure the value of latrines, as much as possible, in monetary units. Economies of scale would suggest that all the latrine be identical, or at least be readily adaptable to the various dwellings. This may or may not lead to centralization. In terms of their use, however, even a hardened economist might be forced to admit that latrines are not conducive to economic analysis. Second best would be some other indicator to use as a simple measurement, such as bacterial count or the number of visitors a latrine sees in a given day. Neither of these all-purpose measures could account for the presence of gendered norms reinforced by the latrine. Perhaps one could determine the bottom line based on equity. It is not clear what kind of units would capture equity but any single unit is likely to gloss over the subtleties typical of social issues.

3.5 The Engineer as Development Agent

One of the shifts in engineering values from the onset of sustainability is that it now seems to be more fashionable for engineers to be involved in problems related to the so-called "developing" countries. Indeed, the words "sustainable" and "development" can often be seen side by side. Filion (2010) foresees adding a module to the "Applied Sustainability" course to include the international context and developing countries. It is perhaps here more than anywhere else that the hegemony of economic concerns can be challenged to make way for more social issues. Though a long time coming, this would likely be good news for Durbin (1985) who was frustrated by the reluctance of many engineers to provide services to those most in need, preferring to bestow their services on those with deeper pockets.

Development is often linked with other words, such as "progress", "change" and "evolution". These words generally have positive connotations and are seen to be something "natural". If we superimpose the concept of development on Maslow's hierarchy of needs, development must refer to moving "up" the hierarchy. It is through this hierarchy that we (Westerners) tend to recount our long-term history (the Dark Ages followed by the Enlightenment), so these developing countries are chronologically behind us and they need to catch up, as it were. The question arises if we see these changes as necessarily good things, things to be desired. Gagnon, *et al.* (2010) describe a "Typical Relationship" of "Cultures and Subcultures" (one of 13 "Framework Components" of an engineering project) as: "Capacity to mobilise people eager for change which share a progressive subculture or ability to convince people resistant to change which share a conservative subculture" (p. 62). "Change" and "progressive" are closely linked and it appears that those that resist change must be convinced otherwise and acknowledge the error of their (old) ways. Oddly enough, the very idea of sustainability itself should counter these biases as some of the "changes" arising from "progress" may not be such a good thing after all (see, for example, Rockstrom, *et al.*, 2009).

Development, progress, change, and especially evolution suggest that development is something slow that takes a considerable amount of time. A "revolution" would be faster, but that sounds too violent, too much against the establishment. The one exception might be technological change which, we are told, is very fast, encapsulated in Moore's "law". It stands to reason, therefore that, if we wish to "speed up" sustainable development, we should do so through technology – perhaps adopt Weinberg's (2013) notion of the "technological fix". Edgerton (2013), however, has noted an ironic twist due to what he calls "futurism". With futurism, we don't worry so much about the problems of today, for we "know", thanks to fast technological change, the required solutions will be found tomorrow. The problem is that, as soon as tomorrow arrives, it becomes today, the rhetoric repeats itself, and change is postponed another day. The result is that presentism still exists even as we look to the future.

The installation of latrines in Rajasthan is itself termed a development project. As such, engineers may see it as their "duty" to "modernize" the technology. If modernizing demands ever-higher technology, then development will lead to centralization and its accompanying vulnerabilities and dependencies. At some point, modernization and development cease to be mutually supportive. The context determines this point. In the case of Rajasthan, even the relatively low technology that is the latrine led to centralization in the form of power to keep women under even greater seclusion. If the engineers seek to "modernize" attitudes, as Gagnon *et al.*'s (2010) desire to "convince people resistant to change" would suggest, they must decide which attitudes. Should they concentrate on attitudes regarding hygiene (relatively easy), or attitudes about the status of women (relatively difficult)? The development model may also lead to an attitude in the engineers themselves, namely, "why can't they be more like us?" This sets up an "us-them" divide and is likely to undermine efforts to empower the local women.

3.6 The Engineer as *Dépanneur*

Dépanneur is a *québecois*-french word for the owner/operator of a small corner shop or, by extension, the shop itself. The term literally means "one who gets you out of trouble", referring to the fact that one can quickly pop in and out of the shop at odd hours and pick up an urgently needed item. The service offered here is that of convenience; hence the alternate English term "convenience store". (Incidentally, being a compact, "convenient" term *dépanneur* is used in Montréal by anglophones and francophones alike.)

A value of convenience is a evident in engineering products, particularly when it comes to electronic devices. Mobile phones are convenient, for I can call from anywhere and be reached from anywhere; I no longer need to be tied down to a land line. At times, however, I wish to be unreachable, to be left alone. Although I can turn the phone off, I may have a job where I am on call and must therefore keep the phone on. Convenience turns into surveillance. E-mail, too, is convenient, but comes with the expectation of speedy replies. Convenience now becomes nagging. Bank machines are convenient because, similar to the *dépanneur*, I can withdraw cash at odd hours. Convenience is another form of presentism, a way of not having to look into the future. All these conveniences allow certain things, while disallowing others. And all these devices have a social impact for they allow their users to completely avoid coming into face-to-face contact with people.

Convenience also tends to favour centralization. Department stores and grocery stores are convenient because one can purchase a wide range of goods at a centralized location. Credit cards are convenient because, regardless of where I make a purchase, the charge comes to the same bill. A mobile phone is only convenient because there is a centralized location that is able to transfer and re-route signals.

From an engineering perspective, it's hard to argue against the convenience offered by the latrine to those in Rajasthan. For Westerners having grown up with the indoor flush toilet, this seems like a no-brainer. But conveniences often take away something good. As it turns out, the latrine was convenient for bodily functions, but became an obstacle (*i.e.*, was inconvenient) to social matters. Convenience served the purpose of surveillance; the tool of liberation was easily turned into one of oppression.

4 CONCLUSION

An investigation of engineering values suggests that these values can potentially hinder the shift from "conventional" engineering design to more "sustainable" engineering design. These values are of particular concern when it comes to integrating the more social matters of sustainability, such as equity. The conventional design values considered are associated with science, mathematics, military structure, economics, development and convenience.

Science and mathematics are close allies, favouring universality and value-neutrality. History and other contextual factors are therefore of minor concern. In stark contrast, contextual factors are of major importance when trying to understand social issues. Science also focuses engineering attention on the more physical side of the world we live in, discouraging consideration of the social. Mathematics stresses the importance of measurement. This favours the quantitative over the qualitative, marginalizing social concerns.

Engineering owes many of its values to its military roots. The hierarchy, being the basic organizational structure of the military, is the source of many of these values. The hierarchy speaks of authority, the establishment and centralization. Authority demands compliance, the establishment stresses tradition and centralization honours sameness. All these tend to extinguish the local, one of the backbones of sustainability. Hierarchies create stratification, with each layer operating more or less independently. Engineers tend to work at a single "level" and rarely wander up or down the hierarchy. When superimposed over the physicality of science and Maslow's hierarchy of needs, engineers will gravitate to solving in a sequential order, beginning with physiological needs.

Economics sees money as the measure of all. In those "rare" instances where money fails to work, the next best thing is to use some other, single measure suitable for an accounting book. Those working on the environmental side of sustainability believe that energy provides the appropriate measure. However the subtleties of social issues, having grown out of the context and history, make any single measure misleading at best.

Development speaks of change. This change is typically viewed as taking place within a hierarchy, in particular, Maslow's hierarchy of needs. Development refers to moving up the hierarchy (positive change or progress). The engineering bias sees this change as being largely technological with a fairly direct transfer to the social. However, excessive technological development leads to centralization, creating the problem of sameness as well as making the local vulnerable as they must rely on outside help. More direct social development, such as a change in attitudes, can lead to an us-them divide between the "developed" and the "developing".

Convenience is intended to make our life easier. However, in streamlining some activities, others are disallowed. Mobile phones make communication easier, while making it harder to be left alone. In the case of installing latrines in Rajasthan, as part of a development project, the convenience of relieving oneself at home was turned into a tool of oppression to keep women in greater seclusion.

Having shown possible areas of contention between "conventional" engineering and sustainability, I offer no solution. Indeed, I do not wish to posit engineering as a "problem". Nevertheless, some changes must take place. Fortunately, engineers are very familiar with change, for without change, there can be no design. From a design perspective, these value sets, as presented, might be best viewed as constraints on the road to sustainability. Even then, these are only initial constraints, for the constraints themselves are subject to change.

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