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MASLOW MEETS THE STONECUTTER

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Abstract

Hierarchies are commonly used in engineering to make data more accessible and concepts more understandable. Engineers readily recognize hierarchies and are quite aware of their presence within engineering work. Maslow's hierarchy of needs is also used in engineering, but its presence is much more subtle. Engineering is seen by many to offer many “problem-solving” opportunities which allows engineers to meet their “self-actualization” needs at the top level of Maslow's hierarchy. Yet these same engineers assume that the problems they solve will all be found in the bottom two levels (the more “practical” physiological and safety needs). Neglecting the problems of the higher levels, engineers often find their best efforts compromised as the effects of their “low level” solutions travel up the hierarchy. A good example of this can be seen in the negative effects the installation of latrines in developing countries has had on women. The insistence that all problems come from the bottom and solutions come from the top closes the loop, to some extent, on Maslow's hierarchy. As the tale of the stonecutter reminds us, hierarchies may not be hierarchies after all.

Keywords: Design practice, Early design phases, Social responsibility, Maslow's hierarchy, problem formulation

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1 INTRODUCTION

The toilet is a simple device: a bowl, an outlet for evacuation purposes, a lid to control odours (or prevent things from falling in) and, oftentimes, a flushing system to facilitate the evacuation. From an engineering design perspective it ranks low on the scale of technical challenges but, from the perspective of "needs", it ranks very high. The toilet, after all, addresses one of those primary, basic needs of relieving oneself.

But the toilet is also a very complex device. This complexity is, however, rather difficult to detect, for it is not revealed by inspection of its parts. No depth of knowledge, no breadth of understanding of the intracacies of the bowl, lid or evacuation tube will allow the designing engineer to foresee how the toilet ultimately "works". How it works depends on the context and contexts typically resist simple explanations.

O'Reilly (2010) recounts a tale of installing latrines in Rajasthan in India. The latrine was touted as providing a range of benefits, particularly for women. Latrines offer women greater security as they perform their bodily functions. They can practice good hygiene and pass these practices on to the children. Latrines are also convenient and they eliminate the need to leave the house during the night and in all kinds of weather. Despite all these seemingly incontestable virtues, the latrine failed to deliver on its promise.

The failure of the latrine was not a result of lack of functionality or even poor performance; these were never called into question. Rather, it was that the latrine did not preserve the benefits of *not* having a latrine. And these benefits were significant: the women in Rajasthan would normally hold their bodily functions during the day and relieve themselves after sunset outdoors in the cover of darkness. This gathering of women provided the main opportunity to socialize. With the latrine installed in or near the house, women no longer had the "excuse" to leave the house and their social life suffered as a direct result; they became isolated in their respective houses.

The troubles didn't end there. At times, the selected location for latrine installation was at the front of the house. Unfortunately, men also tended to gather at the front of the house. This compromised the security and privacy the latrine was supposed to offer and the women, not surprisingly, refrained from using the facility. Leaving the house at night, as before, was frowned upon, as it was seen unnecessary, but the toilet wasn't, in the minds of the women, an option, either. The situation had gone from bad to worse. Despite its negative impact, the latrine was still seen as a status symbol: one did not actually have to use it to enjoy this status; in some cases, latrines ended up being storage areas.

Such problems are not confined to Rajasthan, or even India. Anecdotal evidence from those working among the poor of southern Mexico find, once again, the toilet at the centre of woman's issue. Dry toilets were proposed to provide security and privacy to their users in contrast to performing these functions on some semi-private patch of ground. Some of the local women, however, were opposed to dry toilets. The reason was not that it would interfere with their social life, but that it would add to their cleaning life. Unlike the great outdoors, the dry toilet requires cleaning and women were quick to realize that the men would assume that this responsibility would rest in the hands of the women. It would appear that pre-empting the installation of the toilet was a better option than negotiating cleaning roles in the post-latrine world.

2 OBJECTIVE

My overarching goal is to better understand engineering values, the possible sources of these values and how these values are manifested in engineering work. I present the toilet as a case study, where a piece of engineering technology, albeit simple, demonstrates how a product, regardless of its technical strength, can have a decidedly negative impact upon those it is meant to serve. Although this concept is by no means a new one, I wish to show that the ultimate failure of this particular technical solution is consistent with an unquestioned belief in Maslow's hierarchy of needs.

3 APPROACH

Consistency does not mean causality and it cannot be claimed that the failure of the toilet was a direct result of a (simplistic) belief in Maslow's model. Consistency, however, does suggest that an exploration is warranted and that a critical examination of Maslow's hierarchy can potentially increase the likelihood that technical solution will have more positive impacts in the broader social context.

Following this examination, I explore the classification of hierarchies to show how hierarchies can easily morph into other types, posing dangers for the unwary. This shifting can be seen as I further explore hierarchies in the context of science, then engineering and, finally, engineering design. Engineering design arguably provides a more "natural" fit as Maslow's model also speaks of "needs" and "needs" figure prominently in engineering design discourse.
It is not my intent to generalize from a single case study to all of engineering design but rather to provide a vantage point from which we might better understand engineering design in particular contexts. It is not my intent to either validate or invalidate Maslow's theory; the more pressing issue is that the social theories which engineers hold *become* reality as they impose their technical creations on the world.

4 MASLOW'S HIERARCHY OF NEEDS

4.1 Basic concept

What is Maslow's "hierarchy of needs"? In Maslow's (1943) original article, he claims that " [h]uman needs arrange themselves in hierarchies of prepotency" (p. 370). The "prepotency" refers to the tendency that some needs must be satisfied first before other needs can be met. Thus, physiological needs, at the bottom of the hierarchy, must be met before moving to the next level of the hierarchy, safety needs. From safety needs, one moves up to love needs, then to esteem needs and, finally, to self-actualization (a word he borrowed from Kurt Goldstein). Self-actualizatin refers to the need to attain one's full potential; a musician, after all, "must make music" (p. 382).
Maslow acknowledges that the concept of prepotency need not be strictly applied as the boundaries between the five levels are not well defined. There is, however, a kind of catching up, where a higher need can be partially met as a lower need is largely satisfied, but the gap is not normally that great. Furthermore, there are instances where the levels are reversed, such as giving up love for the sake of esteem. At other times, substitutions are made, such as smoking to suppress pangs of hunger.

4.2 A word of caution

In making sense of Maslow's model, one must bear in mind its roots. Maslow's exploration comes from the perspective of psychology; psychology is concerned with the individual. The social context is not generally considered. My need for love is therefore not tempered by the views of those around me. What Maslow *does* claim is that *how* I satisfy the need *is* tempered by my social context.
Psychologists also concern themselves with human behaviour. Some behaviour can be traced back to situation or context; other behaviours have other sources. Maslow is concerned with behaviour that is the result of human motivation and this motivation is assumed to be the result of unfilfilled human needs; needs are the means, and motivation is the end. Maslow's motivation to understand human needs may be quite different from the engineer's motivation to understand needs.
Maslow's hierarchy has been popularized with the rather familiar pyramidal shape. However, such a figure does not appear in Maslow's article. The shape suggests that there are many on the bottom but few on the top. It is not immediately evident what is being counted. Maslow's discussion of the five needs does suggest that the pyramidal shape may be appropriate for the "top" is where one wants to be for it is more satisfying to pursuing activities to allow onself to "be all that one can be" than to spend most of one's time scrounging up a bit to eat or frantically looking for a place to relieve oneself. Furthermore, he states that "basically satisfied people are the exception" (p. 383) suggesting that there are few at the "top" of self-actualization. What is counted therefore might be the number of people directing most of their effort to needs at a particular level or perhaps the amount of time spent having those needs met.

5 HIERARCHIES

5.1 Types of hierarchies

Assuming Maslow's model is indeed a hierarchy, what kind of hierarchy is it? Lane (2006) suggests that hierarchies come in four different forms: order, inclusion, control and level. Each has its own peculiar characteristics.

The *order* hierarchy puts entities in a particular order based on some variable. One example is ranking cities by population.

Lane describes an *inclusion* hierarchy with respect to Herbert Simon's image of Chinese boxes, *i.e.*, of boxes within boxes. Each container, or box, contains only other containers. A level in this hierarchy refers to the number of containers one must open to arrive at the container in question. An inclusion hierarchy precludes the possibility that a container can be contained in two containers at the same level. An example is a city which contains entities such as firms and households which in turn contain people. (One might argue that Lane's example is not a good one as an individual person can be both within a firm and within a household.) Lane sees this hierarchy as making an ontological claim, a way of structuring reality.

Lane sees the *control* hierarchy as the most familiar. Entities are arranged by ranks. Power is concentrated at the highest rank. It is through this organization of power that control can be exerted. There are relatively few (sometimes one) at the "top" and many at the "bottom". Another important concept related to this hierarchy is the that of flow: orders flow down the hierarchy and information flows up.

The fourth and final hierarchy is the *level* hierarchy. Levels in this hierarchy are "characterized by a particular spatio-temporal scale" (p. 85) with the higher levels at more extended scales. Interactions exist between levels. Lower levels maintain and construct higher levels. Thus, upper level entities may be partially composed of lower level entities (akin to "emergent properties", presumably); this is referred to as upward causation. The incorporation at the higher levels can change the properities of entities at the lower levels, giving rise to downward causation. Another interesting feature of the level hierarchy is that, despite the upward and downward causation, each level is fairly autonomous and there need not be any interaction. Examples of this hierarchy abound and can be found in physics/chemistry (elementary particles – atoms – molecules), biology (cells – organs – individuals – species) and economics (individuals – departments - firms – national economies). The autonomy can be seen in that one can study individuals without studying cells.

Lane notes that the boundaries between hierarchy types may be blurred. In the case of the level hierarchy examples, these also form inclusion hierarchies (for instance, an organ is composed completely of cells). An army can be viewed as an inclusion hierarchy in terms of its military units; it forms a control hierarchy with regard to military ranks.

5.2 What Kind of Hierarchy is Maslow's Hierarchy?

Maslow's hierarchy, like the military hierarchy, cannot be easily confined to a single type. In fact, Maslow's model aligns with certain features of all four types.

As an order hierarchy, Maslow's model ranks the needs in order of importance. From the perspective of biology, the physiological needs are the most important; from the point of view of meaning, self-actualization would be the most important.

As an inclusion hierarchy, we can think of Maslow's hierarchy as consisting five containers, one inside the other, much like the Russian nesting dolls (*matreshka*). The outermost container represents the need of self-actualization. We look inside the container to discover what "makes it tick" and find the self-esteem container. At the deepest point, the smallest container represents the physiological needs. Maslow's model exhibits the "inclusion" feature in that, in the "extreme" case, all needs of a lower level must be satisfied before moving on the next higher level.

Most depictions of Maslow's model assume a control hierarchy. The first obvious control feature of these depictions is the triangular shape: there are many at the bottom, and few at the top. The many correspond to physiological needs, and the few, to self-actualization. The "few at the top" assumption is justified by Maslow himself admits that "basically satisfied people are the exception" (p. 383); the "many at the bottom" presumably represents the "bottom billion" of the world's population struggling at the lowest level. Hence, it is also more desirable to be at the top than at the bottom. In terms of flow, freedom flows up (as we satisfy our more basic needs, we become more free to do what we really want) and purpose flows down (self-actualization gives meaning to the more basic activities carried out to satisfy the lower needs). The one reason why Maslow's model might not be a control hierarchy is simply because Maslow (1943) does not mention control. This may be because Maslow, as a psychologist, focuses on the individual rather than on groups of individuals, where some exert control over others. Despite its conspicuous absence, control is a very important issue and we shall return to it presently.

The level hierarchy also provides a nice fit to Maslow's model. Consistent with Lane's description, each level exhibits a certain amount of autonomy. One can carry out lengthy discussions about esteem without ever having to mention anything about security. At the same time, some of the entities from the lower levels migrate into the higher levels. Upward causation captures the idea that the higher levels only come about after the lower level needs are largely satisfied. There is also downward causation, and this, too, will be explored momentarily.

The ability of a hierarchy, such as Maslow's, to shift types shows the importance of knowing what the various types are. Engineers, assuming themselves to be working under the guidance of a "value-neutral" hierarchy within the technical realm may find themselves inadvertently supporting particular political powers if they fail to notice the shift to the control hierarchy. This will become more evident as we work our way through hierarchies as used in science and engineering.

5.3 Hierarchies in Science

Hierarchies in science are very common and, for some of us, this is the first place where we became familiar with the concept. Early on, we are taught the classification of organisms. This is an excellent example of an inclusion hierarchy. A cat (inner container) belongs to the cat family (outer container). There is no animal which can simultaneously be, for example, both a cat and a dog (*i.e.*, no overlapping boxes). This classification scheme originates in human social structures, as evidenced by the common use of the term "family". This hierarchy also morphed beyond animal classification with Darwinianism coming on the scene. The classification scheme took on a chronological order and came to speak of the history of organisms. As a history, the hierarchy came to capture the notion of *development.* With this later version, the inclusion property remains essentially intact as two similar entities are assumed to have the same point of origin. All cats, for example, are assumed to have the same ancestor if you go far enough back in time.

Science also employs the control hierarchy. Once again, drawing from biology, science speaks of the animal "kingdom". The animals in this "kingdom" are supposed to have their various roles to keep the "kingdom" running. We thus have the "food chain" or trophic levels. There are relatively few entities at the top (the predators) and many entities toward the bottom (the prey). Order flows down (in this case, in the form of population control) and food flows up. It is worth noting that the ordering of the food chain under the control hierarchy bears some resemblance to the ordering of organisms of the classification scheme of the inclusion hierarchy.

Examples of the level hierachy in science we have already seen through Lane's examples. These have very much a "building block" feel to them as small entities (atoms) are put together to make larger and larger entities. Perhaps a more illustrative example of the level hierarchy in science would be the arrangement of science itself. We can place physics at the bottom, then chemistry, then biology, then psychology, and then sociology. In many ways, this echoes the previous hierarchy (elementary particles – atoms – molecules); this should not be surprising. Biology, in many ways, views life as a complex of chemical reactions. Perhaps more in keeping with Lane's definition is that the layers can co-exist quite independently. Most universities, for example, have a department of physics which is quite distinct from a department of chemistry.

These same sciences can be arranged to form a control hierarchy. Physics (for some, at least) sits at the top, as the ultimate authority on (physical) reality. The idea of the "few" at the top is captured in the fact that physics is confined to a small number of entities governed by a small number of laws. All those sciences below are therefore expected to conform to the order determined by the one at the top. Thus, once again, order flows down. What flows up is all the ways that these "laws" have manifested themselves in various contexts within the other disciplines ("grounding").

It should be noted that this ordering, with physics in the privileged position, has had a profound effect on both science and engineering. Dennett (1995), for instance, discusses how "physics envy" has "distorted" thinking about biology (p. 227). Jumping ahead to engineering design, Eder and Hosnedl (2008) speak of science passing through 5 phases of "maturity", with the final, most mature, phase being that of "quantification, classical physics" (p. 532). This suggests that sciences such as sociology are less "mature" and therefore deficient in certain areas relative to physics.

5.4 Hierarches in Engineering

Perhaps the first indication that engineering relies on hierarchical constructs is that science is said to be "foundational" to engineering; building engineering on top of science speaks of a level hierarchy with upward causation (engineers use scientific theories). The downward causation can be seen in that scientists use machines designed and built by engineers to carry out their scientific experiments. The levels are autonomous in that engineering and science can exist quite independently.

The order hierarchy is arguably more prevalent in engineering design than more analytical side of engineering, and is discussed in the next section.

The inclusion hierarchy is, like science, used for classification purposes. In Group Technology, manufacturing machines are grouped into clusters (*i.e.*, containers) to produce a family (another container) of parts. Engineering components are classified by inclusion hierarchies. At times, strict inclusion is difficult to maintain as a single component may be classified in many ways (e.g., bolts of different lengths can be of the same material; bolts of the same material can be of different lengths). Within computer programming, object-oriented program uses an inclusion structure in its system of classes and inheritance. Within procedural programming, inclusion manifests itself in that loops are nested and cannot overlap.

Since engineering develops control systems, it stands to reason that control hierarchies can find a ready application. There is a centralized system (the "few" at the top) and a network of controlled features (the "many" at the bottom). Like most control hierarchies, orders flow downward; in this case, feedback flows upward. The control hierarchy also figures prominently in the typical engineering workplace; engineers, particularly the younger ones, are presumed to be working under the watchful eye of a supervisor.

5.5 The engineering (design) connection

Engineering design, not surprisingly, makes extensive use of hierarchies as well. The inclusion hierarchy echoes the assembly of parts and the assembly of assemblies. The level hierarchy speaks of systems in design, where a large project, such as an oil refinery, are divided into smaller sub-systems which are then developed fairly independently until the project nears completion. The control hierarchy posits the function(s) at the top with the more concrete supporting parts at the bottom. Purpose or meaning flows downward from the top and performance or behaviour flows upward from the bottom. The lowly order hierarchy is of special interest as it used in many instances to rank diverse ranges of elements according to perceived importance; among these is the ranking of customer "needs".

Ulrich and Eppinger (2008) speak of "organiz[ing] the needs into a hierarchy" (p. 63), the third of five steps carried out to identify customers needs. The hierarchy may consist of only two levels, primary and secondary needs; more detailed importance rankings are carried out in Step 4. Ulrich and Eppinger emphasise that "needs" express *what* the product is to do, not *how* it is to do it. They also state that "[a]ll products are aimed at satisfying needs of some kind" (p. 6). The terminology is rather Maslowian, for Maslow (1943) himself speaks of needs being "satisfied" (p. 370). As we have already seen, Maslow, too, distiguishes between the "what" and the "how".

For Maslow, "what" is concerned with the individual, and "how" with the social context; thus, needs are not social constructs. At the lower levels, this stance seems reasonable but, as one moves further up the hierarchy (e.g., belonging, self-esteem), it becomes increasingly difficult to separate the need from the social context in which the need occurs. The same seems to hold for product development, for can't advertising create a need?

Advertising aside, product development, such as presented by Ulrich and Eppinger (2008), tends to focus on the individual needs over the social. Yalch and Brunel (1996), too, explore product design, and makes explicit reference to Maslow's hierarchy. Noting that there is no emprirical evidence for hierarchical needs, they put the model to the test, asking particpants ("customers") to evaluate a product (with inconclusive results). To a certain extent, given the number of participants, they are obtaining a glimpse of social needs, but the questions are all based on individual preferences.

The idea of using engineering design to address social needs has a stronger presence within, for example, Weinberg's (2013) "technological fix". The technological fix finds solutions to social problems by deliberately circumventing the need for behavioural (social) change. Rather than persuading people to use less water, the "technological fix" resolves the problem, for example, by building nuclear desalination plants to provide abundant, cheap water. In contrast to product design, the customers (those using the water) are not surveyed to determine the features of the product (the desalination plant). This, of course, raises the question of how the needs are identified in the first place; Weinberg is silent on this issue. Perhaps these needs are so obvious (read: basic) that customer input will have little real effect on the design. The emphasis here appears to be on the functional qualities of the product, the domain of engineers.

Equating the functional with basic needs is more explicit in Yalch and Brunel's (1996) product design. Their testing of Maslow's hierarchy assumes that the functional qualities of the product refer to lower needs, and the asthetic to higher needs. As engineers tend to focus on the functional requirements, the needs that engineering addresses will be those of the lower levels.

6 ENGINEERING IN THE MASLOWIAN FRAMEWORK

The design and installation of the latrine in Rajasthan highlights how many of the concepts presented with regards to Maslow's hierarchy play out in the "real world".

The problem, as identified by someone, was centred around issues of convenience, security and hygiene. These three needs map neatly onto Maslow's hierarchy within the bottom two levels. By meeting these needs, the benefactors of the solution would move closer to achieving self-actualization (assumed upward causation).

The solution took the form of a technological fix, namely, the latrine. In fact, this one piece of technology was going to address, in whole or in part, all three issues simultaneously. As a technological fix, functionality comes to dominate, further drawing attention to the lower needs. Yet another downward push comes from assessing the performance of the device using physical metrics: convenience can measured by time saved or the probability of foul weather; security by the barriers to sound and light provided by the latrine walls or location of the latrine; and hygience by bacterial count. The higher needs are less conducive to the physical measurement of performance and therefore receive less (engineering) attention.

The ease with which the solution can be evaluated raises the question of which came first, the problem or the solution? How could one assume that a toilet could address such a range of issues? In a later work, Maslow (1970) himself points this out and likens the issue to that of a drunkard who, having lost his wallet, looks for it under a streetlight where the light is good rather that in the place where the wallet was actually lost. For engineers, the "light is good" on the bottom two layers of Maslow's hierarchy, the light itself being the physical measures they use to verify their solutions.

As it turned out, this approach to verification failed to account for some important issues. The first hint that trouble was brewing was that the solution was initially targeted at individual needs, for a toilet has but a single seat. The *social* need should have been identified from the beginning, for the issues were not simply that of convenience, security and hygiene, but of *women's* convenience, security and hygiene. Unfortunatley, Maslow's hierarchy sees needs (the "what") as independent of social context; gender distinctions therefore can only come into play in the "how". The proposed solution seems to follow suite, with little attention paid to the larger social context. The presence of needs specific to women suggests that the needs are, at least in part, constructed by social context. The physical, functional engineering perspective, focused on the lower level, has little to offer, as gender issues reduce to biology, which may further reduce to the choice of toilet bowl size and shape.

The influence of the social context on the needs of women becomes clearer if we ask why women had their particular needs. Why did women have problems of security? Was it due to wild animals attacking them as they relieved themselves? No, it was more related to men's interference. Why was convenience an issue? Was it because the women wanted to have more time at home to be with the family and get the chores done? No, it was because the men had greater pride if their wives did not have leave the house. Was hygiene more of an issue with women than men? Probably not, but it was the women, not the men, who were expected to pass on good hygiene habits to the children.

The complexity arises because there is more than one hierarchy at play. The power difference between men and women speaks of a control hierarchy with women at the bottom. The men's needs must be met ahead of the women's needs. Presumably, the men also identify what those needs are and how they are prioritized. Even Maslow himself hinted at social divides, stating that "no data are available for unintelligent people" (p. 385); he apparently has no trouble dividing people into two basic groups of "intelligent" and "unintelligent".

The design and installation of the latrine in Rajasthan was part of was it commonly called a "development project". Maslow's hierarchy very much resembles a development sequence. We have already seen development in the context of science, where the initial inclusion hierarchy of animals shifted into a development chart for Darwinian evolution. Framed as development, the issue of power (i.e., a control hierarchy) appears once again, for Escobar sees development work as just an extension of Western domination (Davis, 2003).

The tendency for engineers to concentrate on the lower two levels of Maslow's hierarchy necessarily positions them as politically conservative. Hierarchies, regardless of their origin, tend to morph into control hierarchies and work confined to the bottom will have little to no effect of the power structures closer to the top; indeed, such work may strengthen the structure. From the engineering perspective, this lower level work is dubbed "practical"; paying attention to what is happening at the higher levels is seen as an unnecessary distraction to the more immediate tasks at hand. Indeed this very principle is applied to artificial intelligence, where one of the principles is "to avoid unnecessary reasoning" (Aydın *et al.,* 2008, p. 51). Although this may be in keeping with the engineering value of efficiency, what engineers often fail to recognize is that, as Weinberg (2003) so succinctly puts it, "Power creates practicality" (p. 8). Although Weinberg was referring to slavery, the principle applies to engineering as well: a focus on the practical will reinforce the power structure and engineers will end up treating symptoms rather than actual causes.

The term "needs" itself merits closer scrutiny. If engineers, according to the standard starting point of design, address needs, why do they confine themselves to only two of the five "needs" levels?

Brugha (1998) believes that the term "needs" should not be applied to all levels of Maslow's hierarchy. Looking from the perspective of "introverted decision-making", Brugha sees movement (in the form of development) through three "levels of commitment": somatic, psychic and pneumatic. The *somatic* (from Greek for "body") refers to the tangible things of this world, to one's own abilities and possessions. The term "needs" is restricted to the somatic-level problems where the focus is on constraints and obstacles. The somatic level corresponds to Maslow's physiological and safety needs. The *psychic* is concerned with one's preferences. At this level, ideas are evaluated in accordance with its acceptance among others. The psychic stage is also where one, for example, avoids responsibility by bargaining. This level corresponds to Maslow's needs of love and self-esteem. The *pneumatic* is about pushing oneself in terms of development, striving, implementing, accepting and receiving. The pneumatic corresponds to Maslow's level of self-actualization. In short, these three "plateaux" can be thought of as needs, preferences and values.

Brugha's first of these three levels correspond well to the engineering concept of "needs". Engineers are generally comfortable dealing with tangible needs as they are bounded by contraints and offer the hope of measurability. Engineers do deal with preferences as well, but to a lesser degree for preferences can appear to be frivolous, *i.e.*, indulgent "desires" rather than "true" needs. Preferences draw attention to user-friendliness rather than the more pressing issues of function and performance. And the engineering training in the "foundational" science and mathematics cannot prepare engineers for addressing issues of value.

As for the women in Rajasthan, they *need* to relieve themselves; they *prefer* to do so under certain conditions; they greatly *value* the time they have to socialize (and perhaps to get out of the house). Herein lies the downward causation of the level hierarchy. As the effects of the installation of the latrine travelled up the hierarchy (upward causation), they eventually entered into the love and esteem levels. The negative impact at these higher levels was so great that it *caused* the rethinking of how to satisfy the physiological needs.

7 WHEN IS A HIERARCHY *NOT* A HIERARCHY?

With so many ways to deconstruct and reconstruct Maslow's hierarchy, we must consider that it may not be a hierarchy after all. Brugha (1998), for one, believes that Maslow's model is not a hierarchy, but rather a sequence.

Engineers are no strangers to sequences. Ask any engineer for an example of a sequence and he or she, particularly if working in engineering design, will likely mention the design process. As a sequence ,the design process consists of a series of steps which are (generally) carried out in a particular order. These steps are also carried out with a particular aim in mind. In other words, a sequence is goal-oriented. Lane (2010), however, makes no mention of goals in describing the four types of hierarchies. From this perspective, Brugha's claim is well taken.

The concept of goals is central to Maslow's (1943) model, for he states that a motivational theory "should stress and center itself upon ultimate or basic goals rather than partial or superficial ones, upon ends rather than means to these ends" (p. 370). The goal of satisfying physiological needs is to be able to then address safety needs. The ultimate goal is to satisfy the need of self-actualization. Alternatively, we might say the satisfying of physiological needs is the means to the end of dealing with safety needs.

The means-end mentality is common among engineers. Engineering is the means to some lofty, duty-bound end; engineering is never an end in itself. This is why engineers speak of the “practical” and the “application” of science and mathematics (thus science and mathematics constitute the means to the end of engineering). Science, according to Maslow (1970), is very much means-oriented and he criticized science in that it pays more attention to how well an experiment was carried out (the means) than on the significance of those results (the end). (He also point out that this is how science remains “pure”.) But might a well carried-out scientific experiment be an end in itself? If Maslow himself is not satisfied with the scientific experiment as an end, might he insist that self-actualization be a means to some unspoken end?

We can ask the same question concerning the sequence we call the design process. What happens when we reach the end of the design process? The answer is simple: we do it again. This is why engineers speak of the design *cycle* or design *iteration*. Might Maslow's hierarchy be a cycle?

8 CLOSING THE LOOP

8.1 The Stonecutter

There was once a lonely stonecutter who was hard at work, chiselling at a rock, when the king went by carried by his servants. “Oh, to be rich and powerful like the king!” thought the stonecutter, “then I wouldn't have to cut rocks all day long!” The stonecutter suddenly found himself in the king's place. But it was hot that day; the sun was relentless. The stonecutter, thinking the sun to be more powerful, wished to be the sun. He was then turned into the sun. He shone his bright light down on the earth and delighted in how all the people scrambled to find shade. His glee was interrupted when clouds got in the way and suddenly, he wasn't feeling so powerful. So, upon wishing to be the clouds, he turned into clouds. He lashed out rain upon the earth, and watched as debris got carried away in his floodwaters. But there was this boulder which was totally unmoved by the waters. Clearly, to be the boulder was better, for it was much stronger than the clouds and rain. So, he became the boulder. It wasn't long before he felt a chip, chip, chip on his side. The boulder was still not powerful enough, as he was helpless against the chisel of the stonecutter.

This ancient story, which I heard as a child, shows us that, what, at first glance, appears so clearly to be a hierarchy, was not a hierarchy after all. Should we introduce Maslow (or perhaps his loyal followers) to the stonecutter?

8.2 The engineering “application”

Engineering students study hard and work long hours in the hopes that, upon graduation they will find a good job. The good job is one that pays well, has the potential for promotion and possibly travel and allows them to use all their engineering knowledge and skill (and then some) to solve (technical) problems. It is here they are at the top of Maslow's hierarchy, immersed in self-actualization. And what are they designing in the midst of all this unleashed potential? Well, toilets. All that self-actualization just to find oneself back at the bottom level of Maslow's hierarchy!

It's not that this is a bad thing, for one can indeed have one's self-actualization needs satisfied in designing and building toilets. However, to be truly in the throes of self-actualization, one must design on one's own terms; the design is the way it is simply because the designer wants it so with no further justification required. Engineers obsessed with “application” and the “practical”, where everything they do must be “useful”, never have their self-actualization needs satisfied. To experience self-actualization, they need to reserve part of their design activity to doing that which they think is worthwhile without waiting for someone else's approval. Research in engineering design, for example, should not just be targeted at creating a better product, but also at making the design activity itself a more enriching experience.

The point of self-actualization is that it is an end, pure and simple, and not the means to anything, much like happiness is not the means to anything (yet it remains extremely important). When you are at the top, you can forego the bathroom breaks, you can ignore the hunger pangs, you are not worried about your security, you can forget about your responsibilities. You are not even thinking about your preferences, for you are in your element; preferences no longer apply. The rest of the world can wait. You are, in essence, home. The means-end oriented engineer is never really home. This is, in part, the legacy of engineering's military past, for the engineer is the soldier on the battlefield, dreaming of home, but kept away by an overwhelming sense of duty.

9 CONCLUSIONS

The toilet or latrine was considered to be the solution to women's needs of convenience, security and hygiene. It failed because the designers neglected to take into consideration issues of gender and power. Simplistic views of Maslow's hierarchy offers one explanation of why this occurred.

Engineers are familiar with, and comfortable working with, hierarchies. Engineers are also familiar with Maslow's hierarchy. Presented as a hierarchy, with essentially value-neutral qualities, it can find a welcoming home in the engineering mindset. A manifestation of the influence of Maslow's hierarchy on engineering thinking is that engineers confine themselves almost exclusively to the bottom two levels.

Maslow's hierarchy can be interpreted as an order, an inclusion, a control or even a level hierarchy. Thus, the motives of those promoting the hierarchy cannot be clear. As a control hierarchy (the typical depiction of Maslow's model), with the top level being the desired position, reserved for the few, and the bottom being the undesired position, reserved for the many, power becomes the central issue. However, issues of power are seldom mentioned as being an integral part of Maslow's hierarchy; engineers may therefore not be aware that this power emanates from the top and, by concentrating their efforts on the bottom two levels, their work will have little effect on the power structure. As a level hierarchy, engineers understand the upward causation in that satisfying the lower needs is an important step to satisfying the needs of the higher levels, but overlook the downward causation whereby negative impacts on the higher levels may undo seemingly positive steps on the lower levels.

In some respects, Maslow's model is better viewed as a sequence rather than a hierarchy, for it protrays a developmental process with a goal at the top. Thus, Maslow's model is actually a means-end sequence. The two ends of the sequence can be joined, and Maslow's model becomes a cycle. This cycle is all too evident in engineering, for engineers, delighted to find themselves in the act of problem-solving at the self-actualization level, quickly find themselves back at the bottom, designing devices for low level needs. Engineers must not forget that, at times, engineering work can meet the need of self-actualization, *i.e.*, be an end in itself.

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