Conflicting Models of the Product Life Cycle:
Worldviews and the Design of Technology

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Abstract

In teaching engineering design we often use an ecosystem perspective on the product life cycle of extraction through disposal. Yet other views of the product life cycle exist, such as the business model, the diffusion model, and various user models. The business model is very widely held and more influential in practice than the ecosystem model. While they are all very different models, all but one assumes the general model that products come and go. This article brings together the various models of the product life cycle in one reading, which might encourage resolution of the deep conflicts among these perspectives as well as be helpful to students studying design. We end by suggesting a meta-model of the product life cycle that would allow designers to see all the perspectives simultaneously and even to add new ones.

This review should improve a student's ability to communicate effectively with others about the development and operation of technology, and also to understand how, and why, conflicts must inevitably arise in the design of technology, even without the political differences that occur using any given model of the PLC. The intent is to create a reading that offers students breadth in understanding how technology functions in society and how, why, and for whom we design, and with what consequences.

Introduction

In this article we explore different models of the product life cycle (PLC), each of which is derived from a different world view. Students of engineering design should understand these different models of the product life cycle, what each can teach us about design and about the different world views of different stakeholders. This understanding should improve student's ability to communicate effectively with others about the development and operation of technology. It should also help them understand how, and why, conflicts must inevitably arise in the design of technology. The intent is to create a reading that offers students breadth in understanding how technology functions in society and how, why, and for whom we design, and with what consequences. We understand that we are only lightly covering a very large content area, but we hope that we identify many pathways for readers to follow while conveying the intent of the paper.

The General Model of a Product Life Cycle

Each model of the PLC describes reality with varying degrees of veracity and completeness, but each model differs from the others because of the different world views (mindsets) of the proponents more than the different degrees of veracity or completeness of the model. They tend to focus on different characteristics of PLCs, which makes dialog difficult. However, we assume at outset that product life cycles all *really* have the following characteristics, regardless of the world view taken.

1. Products come and go.
2. PLCs create Flow-Throughs (FTs) of energy and materials.

3. The Total Flow-Through (TFT) of PLCs transforms society and transforms the environment in ways that may or may not be sustainable, and that may or may not create a better world.
4. The TFT has major impacts on things such as productivity, human health and happiness, resource depletion, environmental impacts, species loss, ecosystem resilience, and the generation and distribution of toxins. Crises in any of these can lead to a collapse of the general model.
5. Most PLCs are currently supported by global supply chains, and, as such, have weakened chains of visibility and accountability. However, localized, autonomous PLCs do represent an alternative to the global interdependent model and thus raise the idea of a second general PLC model: a distributed, largely unlinked, autonomous, localized, *production-use-disposal* model. And two models raise the possibility of a hybrid model that might plausibly describe reality most accurately and provide a metric for where we are in the continuum between the two.

Commentary on the General Model

Technology is human behavior that always transforms society and the environment, sometimes to the extent of changing what it means to be human and the fundamental nature of the ecosystem.   Human spaces are now dominated by the sciences of the artificial (design), and the technological density of our lives steadily increases with ever increasing numbers of successes, failures, and learning curves in our culture. Design is the cornerstone of technology. Design is how we solve our problems, fulfill our needs, shape our world, change the future, and create new problems and new opportunities. From extraction to disposal in the life cycle of a product, the design process is where we make important decisions; the decisions that determine most of the final product cost, and the decisions that determine most of the ethical costs and benefits. Everything is designed but not everything is designed well, and the sheer volume has now become critical.

According to a recent analysis in the Economist,[1] most of the economic activity in human history has taken place in the 19th and 20th centuries. The world population has grown 10-fold since 1811 and when the growth of per capita gross domestic product (GDP) is factored in, the results are even more remarkable. “Over 23% of all the goods and services made since 1AD were produced from 2001 to 2010, ...” That is, almost a fourth of all the goods and services produced in the last 2,000 years were produced in the last 10 years. It is hard to believe that this exponential growth has a very long future, even if it is more exaggerated than growth rates in the TFT of energy and materials.

A recent dichotomy, which vividly depicts an inter-model conflict, is the economic belief in salvation through shopping contrasted with the possibility of the “end of shopping.” One pole of this dichotomy is seen in a Washington Post article by Robert Samuelson in 2008.[2] Samuelson’s article was framed in a downturn in the business cycle. He noted that “consumer spending equaled 70 percent of [US] GDP” and is one of the main drivers of the global economy. Samuelson called for the return to shopping by confident consumers as soon as possible.   In contrast, the 2011 book by environmental activist Paul Gilding sees a fundamental end to shopping and the collapse in the general product life cycle model as almost inevitable because of global climate change.[3]

Gilding’s view is that we need to seek more happiness, not more products and services. This can be pursued in some of the models we review below such as the user views, particularly in affective design. In Buddhist terms, Gilding's position is that we need to pursue the Gross National Happiness Factor [4] (former Bhutan King Jigme Singye Wangchuck) rather than the GDP or Gross National Product (GNP). [5] The idealism in Gilding may be the idea that we can change by design rather than by catastrophe; that we are capable of proactive evolution. He spends most of his book trying to persuade us to be rational and he is not convincing. But the "end of shopping" is certainly a teachable moment.

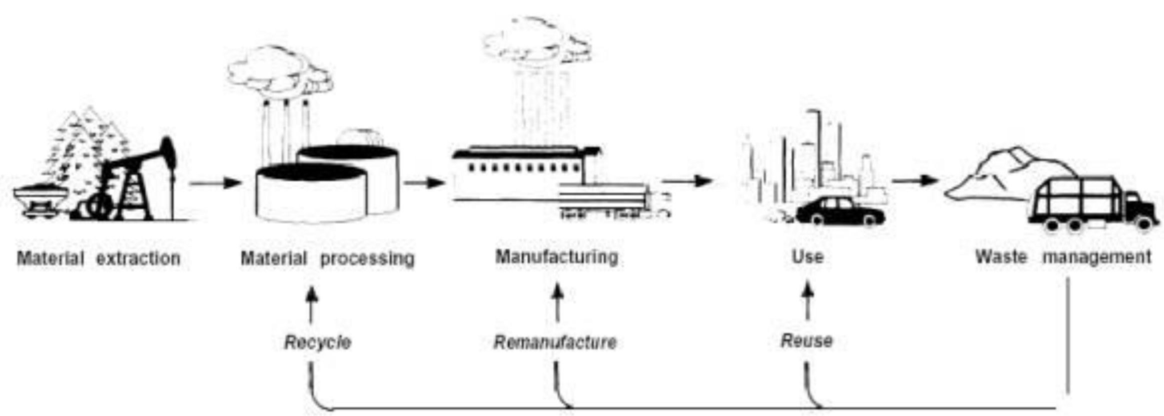
All technologies have life cycles, even those intended for permanence, but how these life cycles are described varies considerably. The differences among models of the PLC is one way of capturing how very differently people may view the same product. Products mean profits or jobs to some, pollution or unacceptable injury and death rates to others, bring great utility or pleasure, or are an intrusive and unwelcome presence in a household, community or nation.

The benefit of this analysis is to explore how what we view as design knowledge is not only variable in very significant ways but how those ways reflect different world views embedded in different social formations and different personalities. Students can then readily see how design is, as Herbert Simon portrayed it, an essentially normative process for achieving human ends using the sciences of the artificial.[6] By incorporating the most popular models in one review, the approach should be open to most, and almost everyone will recognize and identify with one or more of the models. This inclusiveness is central to what we hope to achieve.

A common way to depict the product life cycle in design is shown in Figure 1-1 from *Green Products in Design (1992).*[7]

4 • Green Products by Design: Choices for a Cleaner Environment

Figure I-I-Stages of the Product Life Cycle



Environmental impacts occur at all stages of a product's life cycle. Design can be employed to reduce these impacts by changing the amount and type of materials used in the product, by creating more efficient manufacturing operations, by reducing the energy and materials consumed during use, and by improving recovery of energy and materials during waste management.

SOURCE: Adapted from D. Navin chandra, The Robotics Institute, Carnegie Mellon University, personal communication, March 1992.

However, several other views of the product life cycle exist, such as the business model and the diffusion model, the former being even more influential in how technology is practiced than the ecosystem model. We will explore these other views, and then we will suggest a meta-model of the product life cycle that allows designers to see all the perspectives simultaneously and even to add new ones.

Models of the PLC: A Summary

Outline

1. The ecosystem view
2. The social transformation view
3. Institutional views: business and government
4. The prestige model of permanent technology
5. The user views
    a. The utility model
    b. The affective model
6. The rational (ethical) model

1. The Ecosystem View: The Planetary Perspective

The conventional eco-cycle model of the PLC is shown in Figure 1-1. Traditionally, this PLC assessment is focused on the ecosystem, its resources, and its sinks. This model is used to identify resource limits (eg, peak oil, the peak ocean fish catch), species loss, pollution loads, and other systemic perturbations (eg, stratospheric ozone depletion, global climate change, antibiotic resistant bacteria, and toxic releases). The idea of sustainability has become the organizing principle for ecosystem-centric design (ecodesign).[8]

A planetary perspective began to emerge out of the environmental movement marked by classic books such as Aldo Leopold's *A Sand County Almanac* (1949)[9] and Rachel Carson's *Silent Spring* (1962).[10] The post-WWII industrial and chemical boom led to considerable environmental damage. This triggered a greater awareness and concern about the environment and led to a host of statutes aimed at managing technology that continues today.[11] January 1, 1970 saw the passage of the U.S. National Environmental Policy Act (NEPA)[12] written to "...encourage productive and enjoyable harmony between man[sic] and his environment." A new field of study arose in civil engineering - environmental engineering. Beginning with a focus on how to manage and deal with wastes after their production, environmental engineering now deals more completely with environmental risk and safety by also developing new production processes that reduce or eliminate certain waste products. So, environmental objectives moved upstream into the design process, hence green design, which, in turn, applies to all engineering practice. One of the first publications to use the term was the Office of Technology Assessment's *Green Products by Design* (1992).[13] "Green design means practicing engineering with the inclusion of natural systems, both as a model and as a fundamental consideration, for the improvement of the quality of all life. Essential to the idea of green design was moving environmental considerations from upstream product manufacturing to the product design process."[14] Leading exponents of this view include Papanek, Graedel and Allenby, McDonough and Braungart, and Leonard.[15]

2. Social Transformation View: Sociocultural models

Technology transforms the environment and society; always. Eco-transformations are considered under the planetary/ecosystem perspective above. Here we will identify several worldviews of the PLC from social and cultural perspectives.

a) Technological innovation as the prime economic driver: This is the theory that innovation (creative destruction), and the creation of ever new PLCs, is central to economic growth (Schumpeter [16]). Progress in technology does account for a large part of economic growth, but it is not a new idea, not even when Schumpeter was writing about it. Innovation to create new PLCs to satisfy venture capitalists was a driver for the first European settlers in North America in the early 1600s.[17] It is embedded in the Constitution of the United States.[18] It is still a very widely and very strongly held belief and a perennial rationale for the benefits, and the costs, of modern technology. It has been a staple of policy from Jamestown until today.

> '"We need to out-innovate, out-educate, and out-build the rest of the world," Obama said before a joint session of Congress [State of the Union, 2011]. "We have to make America the best place on earth to do business." If there was a central theme to the president's remarks, it was innovation. He called for more investment in education, research, science and clean energy.' Forbes[19]

Unfortunately, the ambition level of immigrants, always a driver of growth and innovation in the United States, has been severely constrained by policy in recent decades where the untrained and illegal immigrants are favored over the educated and legal immigrants who start new companies at twice the rate of the native born.[20]

b) Technology as the determinant of culture: Technological determinists (Ellul,[21] Drucker,[22] White[23]) like to describe eras in terms of the technologies and the product life cycles that shaped them; from the agricultural technologies that created surpluses and then trade, cities, governments, armies, and religions in ancient Mesopotamia (Drucker, *op cit*), to air conditioning promoting migration southward in the United States. In this model, it is culture that is directly shaped by technology and product life cycles are often viewed in design from the perspective of consumers, or victims in the case of product liability and recalls. Designers focus on customer needs, but they can, too, use scenario design and anticipate human futures resulting from current design ideas.

c) Technology transport phenomena: There are models of the ways technologies are actually adopted and diffused. In these models, technology, like a contagion, can be transported and incorporated via various pathways. For example, the diffusion/adoption model of *innovators, early adopters, early majority, late majority*, and *laggards* is based on the work of Everett Rogers.[24] Malcolm Gladwell's work in *The Tipping Point*[25] also falls into this category, where he examines how products go from relative oblivion to becoming a market leader via facilitated transport by various human actors. Diffusion is a holy grail for many types of design, and successes range from the Qwerty keyboard to Coke and the iPhone. Laggards in other countries may feel it is a form of imperialism, hence the banning of Coke in India, or the charge of monopolistic practices as has been frequently charged against Microsoft in Europe.

d) Society as the shaper of technology: Social constructionists view technology as arising from the culture within which it is born.[26] The product life cycle is viewed in terms of who created the technologies and why. In 1969, George Daniels famously inverted the thesis that technology shapes society by showing how often it was just the opposite that took place, such as the cotton gin being invented to deal with a surplus of cotton rather than creating such a surplus.[27]

Lynn White, who argued a determinist thesis that the plough and the stirrup shaped medieval Europe (op cit.), also argued (Wikipedia) a constructionist thesis that Judeo-Christian theology is fundamentally exploitative of the natural world because:

1. The Bible asserts man's dominion over nature and establishes a trend of anthropocentrism.
2. Christianity makes a distinction between man (formed in God's image) and the rest of creation, which has no "soul" or "reason" and is thus inferior.[28]

Most engineers hold this constructionist view, since they are part of the social construction processes. This is especially true in design. Design educators have embraced this in design education by adopting a social process model of design in recent decades.

3. Institutional Views: Business & Government.

The standard business model of the product life cycle is Introduction, Growth, Maturation, Saturation and Decline based on the supply and demand and the corporate return on the investment. [29] There are important technical PLC models within this industrial model such as Product Lifecycle Management (PLM).[30] which maintains the knowledge base for a product and is usually integrated in high-end Computer Aided Design (CAD) systems.

Products have a birth, a life, and a death, and they are financed and marketed with this in mind. Product sales and profits start at a low level, then rise until market saturation occurs for the product type (and market share stabilizes for a particular product). This is followed by a decline to a low level, and then a phase out, or sell off. Profits for a company’s product often collapse at the end of one or more patents (now 20 years in NAFTA countries). Philip Kotler,[31] paraphrased and expanded below, breaks the product life cycle (PLC) into five distinct phases:

i) Product development. This is the phase when a company looks for a new product. New products do not have to be disruptive technologies, although these may have bigger profit margins initially (like the video-cassette recorder, compact disc, cell phone, or smartphone). They may be merely additions to existing product lines (the first cigarette with a filter tip, for instance) or improvements to existing products (a new whiter-than-white washing powder or toothpaste, or more legroom and better mileage in this year’s model of a car). In fact, such redesigns make up the bulk of all design activity and serve to keep the capital investment in the PLC going as long as possible until, like the disposable camera faced with mobile phone cameras, they just collapse to niche markets or oblivion.

ii) Introduction. The product’s costs rise further as the expense of advertising and marketing any new product begins to take its toll; the introductory push needs to be intense at the onset. But the probability of a strong market response must be determined far earlier during the front end engineering design (FEED).

iii) Growth. As the product begins to be accepted by the market, the company starts to recoup the costs of the first two phases. The break-even-point is when the revenues match the current expenditures. As revenues exceed expenditures they generate a return on the investment (ROI) that has been made in the PLC to date.

iv) Maturity. By now the product is widely accepted and growth slows down as market saturation occurs even overseas. A successful product in this phase will come under pressure from competitors. The producer will have to start spending again in order to defend the product's market position. The Intellectual Property (IP) rights that protect the product come under fire in what is usually referred to as "patent wars." These wars are fought between those who seek to gain income from the PLCs of others, and those who seek to protect their own PLCs. Most companies engage in both and it is a complex scene that only occurs when there is a great deal of money at stake. For example, in 2011 Apple and Samsung are going head to head in the smartphone and tablet markets and both suing each other. Remarkably, Samsung makes 25% of Apple's iPhone, in addition to its own products and makes very sensitive decisions about how to deploy its resources. In fact, Samsung manufactures all of the Apple A4 and A5 package on package (PoP) system on a chip (SoC) contained within iPad, iPhone, and iTouch.[32]

v) Decline. Ultimately a company will no longer be able to fend off the competition with acceptable profit margins, or a change in consumer tastes or lifestyle will render the product redundant as disruptive technologies that create new markets with new ways of doing things sweep the old ones aside. For example, by the end of the 1990s, cell-phones had largely replaced land lines in Finland, and many other countries followed. All stages may be played out globally and some PLCs may linger on in developing economies for many years. This can happen for products that get banned in advanced industrial societies where laws are stricter. One example is DDT, banned for agricultural use in the US in 1974, yet not banned worldwide for agricultural use by the Stockholm convention in 2004. Today DDT is still manufactured in India and China, albeit ostensibly only for vector control and not agriculture.[33] And the end of a patent, 20 years under NAFTA, usually triggers intense competition and lower prices as in generic drugs.

Products of fashion, by definition, have a shorter life cycle, and they thus have a much shorter time in which to reap their reward. A distinction is sometimes made between fashion items, such as clothing and accessories, and pure fads, such as the notorious pet rocks. It is not always immediately obvious into which of these two categories a product falls. When they were first introduced in the early 1980s, in-line skates seemed as if they might be a brief fad. But 25 years later they were still selling strongly, firmly set in the mature stage of their life cycle. They may not be destined for the life cycle of the corn flake, but they have already outlived many seemingly more permanent products. Only the future can decide the longevity of a product, so in hindsight we marvel at the QWERTY keyboard, the dial phone, and the ethernet protocol. And proponents of sustainable design should seek clues that explain their successful longevity.

Government views of PLCs occur in different ways in policy, procurement, design, realization, and in use. Their PLCs typically lag the market in introduction and in abandonment, with the exceptions of technologies for defense and prestige, and they usually suffer from elevated costs.

Both business and government approaches to the PLC are that of social construction and government policies and corporate strategies reflect this. However, statutes that manage the impacts of PLCs, such as clean water and clean air acts, have grown exponentially since the 1970s.[34] As a result, corporations try to anticipate the trajectory of regulations on technology through such tools as scenario planning, eg, Shell,[35] and through lobbying to get the regulations they want and, on occasion, write.

Ulrich and Eppinger's *Product Design and Development*, exemplifies the business model of a PLC in design education.[36] It has been widely used in engineering design education since the first edition in 2000.

4. Prestige Perspective

This is the category, very important in history, where a conventional PLC may not be envisioned. Rather, a product is created for permanent use, and such products are often designed to be singular. The reason is usually prestige by governments, corporations, and individuals. Examples include many buildings such as the Eiffel Tower, the Burj Khalifa, and the Empire State Building. They also include nationally promoted technologies like those of the US space program, the Three Gorges Dam in China, the supersonic Concorde or high speed rail in France. Some of these induce crippling debts. For example, the Burj Khalifa was called the Burj Dubai until, at the point of completion in 2010, Dubai ran out of money in a global economic downturn. It turned for help to the neighboring oil-rich emirate of Abu Dhabi and its emir, Khalipha, and the symbol of the prestige changed.[37]

Prestige also occurs in the individual models assuming a conventional PLC where desire for prestige in fashion has triggered criminal behavior, and in the business model where prestige drives up-scale marketing and even mass marketing using prestigious icons. The effect of prestige on product selection is seen across age groups. In a study of clothing choice among adolescents, in general those with the highest self esteem most valued utilitarian design elements while susceptibility to interpersonal influence (i.e. peer pressure) was associated with the importance the adolescent placed on prestige related display elements[38] The message sent in fashion is the point. It is worth noting that the word prestige derives from the Latin word "praestigium" meaning "delusion, illusion, and even to trick.[39]

Corporate visual identity (CVI) drives corporations to regularly purchase products to enhance their prestige.[40] For example, corporate offices are built symbolically robust and tall (e.g. Sears Tower, Chrysler Building) or surrounded by highly engineered and groomed landscaping in order to project an identity message of prestige. The engineering and costs embodied within these design choices are clearly in excess of purely utilitarian alternatives. Corporations may also purchase prestige products unrelated to their primary business, such as sports arenas to enhance their CVI. These arenas are often purchased with a quasi-permanent time horizon; some are less permanent than others (e.g. Enron Field *aka* Minute Maid Park).

Non-cyclical Quasi-permanent Products

While prestige products defy utilitarianism, non-cyclical quasi-permanent products defy consumerism. These products are often designed and built with little thought to a subsequent replacement model. Products such as dams and hydroelectric power plants (e.g. Hoover Dam), bridges (e.g. Golden gate, Brooklyn), and potable water treatment plants (e.g. 100 year old plants still in operation in the United States) are all large scale civil engineering examples of quasi-permanent engineering design solutions. These products are designed for maintenance, not replacement, their permanence reflective of the importance of their function and the large upfront cost of production. And they are not always maintained well as service loads increase. Bridges are aging everywhere, often with both a deteriorating structure and increased loads. But even if severely damaged or destroyed, prestige products are very likely to be rebuilt as was.

Quasi-permanence is not always achieved. The Maginot line, built on the heels of the Franco-Prussian and First World wars was designed as a permanent solution to the German problem, conceptual flaws in its design led to its premature demise. Conventional weapons and military supplies that are kept on hand in the event of a conflict are often warehoused beyond their intended lifespan; troops sent to fight in the early days of the Korean conflict did so with surplus WWII weapons and troops sent to Vietnam did so with those from the Korean conflict. Modern examples of quasi-permanent military investments exist in the form of nuclear weapons; products designed and built for their long term psychological utility instead of applied use and often retained in excess of their intended 25 year lifetime. The average stockpiled US nuclear weapon is 19 years with some dating from the 1970s and the US has not produced a nuclear weapon in over a decade.[41] And shifts from war to peace has left hundreds of thousands of land mines in ground trafficked by men women and children.[42]

Buildings, long treated as quasi permanent, have moved steadily towards PLC status. A recent report from the Vice-Minister of the Ministry of Housing and Urban-Rural Development in China contrasted the life expectancy of buildings there (25-30 years) with those in the US (74 years) and the UK (132 years),[43] but this masks much shorter life spans in some cities and housing developments.

In another venue on might also discuss products whose durability is far less or perhaps far more than claimed/ expected/intended.

5. User Views

Customer needs have received a lot of attention in design education in the United States and is central to the business model of a very widely used design text.[44] In some views, more prevalent in Europe, it is the user rather than the customer who is the focus and these roles differ in important ways, not the least of which is that they are not always the same person. See IBM[45] and ISO.[46] Using either customers or users, the needs will be viewed below as a complex of material (utilitarian) and affective (emotional) needs. Usability cuts across this distinction, having aspects of both convenience and taste (eg touch screen or button keyboard on a smartphone).

We will summarize these two models of the product life cycle: i) Utility and material need: the return on the investment to the individual, and ii) Emotional bonding, and the subsets of social bonding through gift giving and risk management which are both affective and utilitarian.

The utility model. In this view people make decisions based on owning something they need rather than want, and do so in a way that is best justified as an investment. Any given decision, such as a car needed for work may eventually be influenced by emotional bonding or enhanced prestige but it is first viewed as making a salary possible that may annually bring an income of several times the investment. A common modern calculus involves energy saving technology. How long does it take for the energy savings of a solar panel or a heat pump to pay for itself? In this world view a threshold is reached when there is a clear material incentive to engage in technologies that pay for themselves in a few years. This calculation can be influenced by government policies that provide tax incentives that, in effect, subsidize the adoption of the technology and considerably reduce the amortization period. For the federal government there may also be a material return to such an investment such as a reduced dependence on foreign oil and the need to fight expensive foreign wars to guarantee the supply chain. President Clinton ordered a significant governmental use of recycled paper in the mid 1990s.[47] This drove the price up to make that enterprise economically viable for the first time, and thus created a policy induced tipping point for the technology.

The Affective Model. Affective design, designing for what people like in a design and how they feel about and bond with a design, has always been important. It has become more salient in design communities in recent decades with books such as those by Jordan, Norman, and Boatwright and Cagan.[48] The latter argue that emotion is the main driver of design choices and hence should be understood by those who design. The related field of industrial design that focuses on the aesthetics and usability of a product has also grown in influence, led by companies like Apple, and it has a large and active professional society, IDSA.[49]

The fashion industry runs on the ability to inculcate a desire to look cool, or at least appropriate, to one's social group. It is not really clear why a tipping point is reached that takes a product from the margins to center stage, but it is certainly not a rational mechanism (Gladwell, op cit). Emotion plays a major role in consumer products as people get considerable meaning in their lives from what they own and the way the feel about themselves. Serious crimes are committed for no better reason than an emotional attachment to a type of jeans, jacket, media player, bike, or car, perhaps because of the serious ridicule that permeates the consumer market. Emotional bonding has led to the new field of affective design, but the world it addresses and helps to create sometimes has as much pain in it as joy. The technological density of our lives continues to intensify. All technologies have problems and fail sooner or later, so the more technologies we have, the more problems we must have with technology. We also have more learning curves, manuals, and hot-lines to endure. All of which add stress to our lives. The fascination with the next technology we will buy helps distract us from the problems we have with those we already own and drives us to the next purchase. New products are now routinely and shamelessly sold with added costs for guarantees against failures, yet many new products are jettisoned while still working for a "better" model. Cell phones and smartphones barely last a year for the "early adopters." The global supply chains of several mineral components of mobile technologies, such as conalt and cassiterite, have been linked to much carnage in the Congo that has most of the world supply of those minerals.[50]

Advertising is largely focused on the emotional drivers of consumer purchases and this experience is now informing design (Boatwright and Cagan, op.cit.). Typically it represents 2-3% of the GNP and in the US it was almost $300 billion in 2007.[51] And advertising must continuously reinvent need as what they told consumers last year must inevitably be over-written by this year's messages. This may be unfortunate. People keep the things they like and some bonding to selected products may bring contentment, and prolonging product use is a mainstay of any program for sustainable technology since it reduces the number of product life cycles. Some people, some of the time, manage to achieve a fairly lengthy use stage with a product where the emotional bonding is sufficient to resist the messages of both advertising and perhaps close friends and relatives.

Affective design is, then, the Achilles heel of planned obsolescence, since, while instant attraction (and aversion to what we currently have) helps sales, if we design for sustained happiness and sustained ownership we will drive down the throughput of energy and materials. We need to define what we want without the help of advertising and its need to continuously redefine what it takes for us to be happy. The small voluntary simplicity movement is instructive in its rejection of most PLCs.[52] And it is here that the discussion of the Gross National Happiness factor needs to occur. How does the PLC model relate to quality of life issues such as technological density/rate of failures/stress. How does a product interact with us during its life cycle - does it enrich our lives or enslave us? Does it make our lives easier and as a result divorce us from experience?

Subset: Social Bonding. A variation in emotional bonding to a technology is in giving gifts that other people will like. Many gifts are given because the giver already likes the product, and the bond may or may not occur for the recipient and may lead to waste. When such gifts are accepted and used it becomes one of many ways in which the users of technology are different than the customers. This is of special significance in gift giving where much waste occurs because material need is less often met or the hoped for emotional connection never takes place - or worse, the result is an aversive reaction. However, gift giving is complex. In most cultures, influence, prestige, and honor are all major factors in gift giving and the nature of the gift economy varies enormously among cultures.[53]

Subset: Risk Management. This complex subject creates its own set of views about products. For many people safety means a safe home, a safe car, and health insurance. Using a TV means exposure to the relentless push of risk management products, from pharmaceutical advertising for health products to mitigate against maladies such as like "restless leg syndrome" and for beauty products that erase time; these products often seem cures for problems invented for the potion.

Yet a large part of the recreation industry celebrates risk and generates PLCs in high risk activities such as mountain bikes, hang gliders, bungy cords, and unpadded rugby shirts. A completely different genre of PLCs are found in personal security products, and yet another in public institutions from local first responders to the forces overseen by the Department of Defense.

All of the above entail a fairly manifest set of expectations. The management of latent risk is much harder to do. Tens of thousands of chemicals have been released in the environment. Most are not tested for all uses and contexts since the uses and contexts are not fully predictable and it is very costly. Further, very little testing is done on interactive and cumulative effects, because that becomes impractical very quickly. This, in addition to the increasing difficulty of understanding modern technology, may be why while statistics indicate our lives are getting safer, people feel less safe.[54]

The unique model of PLCs in risk management is created by the insurance industry, which focuses on product liability and establishes dollar values for human lives, injuries, sicknesses, and the cost of losing a livelihood. Teaching design students about product liability and product recalls is a good way to include this perspective.

6. The rational (ethical) models. Rational/ethical reasoning is the category into which this article falls, and which has its own section since it purports to have general applicability - depending, crucially, on its diffusion beyond the authorship.

Ethical Reasoning. There is a very large body of literature representing the way individuals have reasoned directly or indirectly what makes a PLC good. Many of these focus on sustaining the ecosystem, or socio-ecosystem, and most others focus on what constitutes ethical technology and an ethical PLC without say the use of conflict minerals or child labor. Some have a more utopian cast such as the voluntary simplicity movement (op. cit.), and many communities from the Shakers to the Amish shape their use of PLCs. The major religions also have distinctive takes on technology as noted earlier about Christianity (White op. cit.).

It is unlikely that this sort of reasoned model can have any significant effect on PLC realities unless many other important people are influenced by the reasoning. Thus Gilding's book devotes most time to persuasion and how to bring about change than to anything else, but he is unlikely to succeed in his aim. And individuals may come to a reasoned philosophy about the products in their lives, but municipal waste is only about 2% of all PLC induced waste and one person simply will not affect the big picture directly. However, students who become designers create the PLCs for the many and can have considerable impact on the TFT of energy and materials, and on the social transformations created.

The Worldviews

Obviously these six model categories are underwritten by very different world views. The dominant business model is usually capitalist in nature, and occasionally state capitalist – as in socialist states and socialist sectors of capitalist states such as defense. The diffusionist model documents the results of the business model and may be picked up by technological determinists. Yet it rarely penetrates design education beyond the search for global market share. The individual models include the customer needs model that is popular in engineering design education and is derived from the business model. However, the notion of a user whose needs are more than those of a largely artificial market place is replete with new directions for technology.

Thus buying what you like or are told to like is one variation of the user model but so is the idea of affective design whereby people buy what they truly like and keep the products for a long time thus weakening the business model. User happiness is more than a customer satisfaction survey is likely to measure, and both are very malleable.

Towards a Unified Theory of the Product Life Cycle

One approach that might give us a meta-model is one that lets us characterize a product in terms of what is *embedded and encumbered* in the product. We know a product in use has *embedded* materials and energy in it representing the preceding processes of extraction, refining, and manufacturing, and distribution. But we might also embed values for waste, toxins, habitat loss and other externalized aspects of the global supply chains that brought the product to us. To this we can add the usual characterization of the use stage: energy use and damage caused such as loss of life, health and property and pollution, for example. There can also be metrics for what is *encumbered* in a product: the *expected* further use of energy and materials and environmental impact through continued use and then disposal. In this way we can capture the life cycle at any point in the process. An electric car for example, has little local environmental impact through fuel use, a good thing, but it has much the same embedded metrics for energy and materials as an internal combustion engine running on diesel. If the metrics include system requirements, such as the highway systems, again the metrics are much the same and differ only in refueling infrastructures. Whereas walking to work or using the internet to telecommute would make major changes in the TFT of the activity.

Other parameters for characterizing a product might be social such as measures of economic benefits in jobs and profits and for whom. Conversely, we might have measures for labor abuses, technological equity, resource depletion, and environmental impact.

So a useful meta-model would include metrics for a product that include the energy and materials used in all stages (embedded and encumbered), and similarly for the environmental and social impacts. We could argue about which metrics to use and the values assigned to each, but we would all be on the same stage. Creating such models would be a good research endeavor.

The central challenge to make this model work would be keeping the King of Bhutan, and Gilding, happy. Yet the way out of the dilemmas we have created for ourselves with an unsustainably high throughput of energy and materials, based to a large extent on inculcated needs, must be to take back control over the human needs for which we design. And we can only hope that when we do, the result will be more happiness with orders of magnitude less use of energy and materials. Reasonably enough, Gilding spends much of his book wondering how we might get there from a state that many feel is already cornucopia - and they are already happy. And while the ocean fish catch may have peaked, other resources have not. The U.S. has the most coal and nuclear plants in the world, and it has vast reserves of gas and oil in shales and sands available here and in Canada. This is why its alternative energy program is weak, the material need is not there. And if the North Pole ice cap melts, the U.S, and several other countries, will have access to more oil, not to mention more fishing opportunities and shipping routes. Gilding has to convince people who do not see a crisis that they have one, and people who are happy that they are not. And those who are unhappy now, usually want economic growth not a hug.

Defining such happiness may be more about answering the questions *design with whom* rather than *design for whom*, and *design with what* rather than *designing for what.* That is, we need to establish processes and hope that these will produce better outcomes rather than engage in top down pronouncements of what should happen and for whom. So participatory, open design, and localized PLCs with achievements like Linux, Wikipedia, Creative Commons, Blender.org offer an alternative path to the market which has produced such a prolific outpouring of goods and services in such an unsustainable way. Localized supply chains are a part of this also. As educators, we must keep truths alive even when the potential for change is small.

In *The Opposable Mind*, Roger Martin wrote that the ability to hold two conflicting ideas in constructive tension is a way in which decision-makers can synthesize new and better ideas. The above was written in that spirit, although we have expressed at least six points of view.[55]

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