SUSTAINABLE DESIGN METHODOLOGY FOR INDUSTRIAL DESIGNERS WITHIN AN ORGANIZATION WITH NO ENVIRONMENTAL POLICY

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Jerrod Bradley Windham, son of John F. Windham and Sharon C. Windham, was born November 30, 1975 in Huntsville, Alabama. He attended Weatherly Heights Elementary School in Huntsville, continued with elementary and middle school at Mountain Gap School in Huntsville, and finished high school at Virgil I. Grissom High School in 1994, also in Huntsville. He began undergraduate studies at Auburn University in 1994, receiving a Bachelor of Industrial Design in 2000. Jerrod started working with Push Product Design, an industrial design consulting firm in 2000. He was accepted into the Auburn University graduate program and began work towards a Masters of Industrial Design in 2005, while continuing to work professionally with Push Product Design.

THESIS ABSTRACT

SUSTAINABLE DESIGN METHODOLOGY FOR INDUSTRIAL DESIGNERS WITHIN AN ORGANIZATION WITH NO ENVIRONMENTAL POLICY

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Industrial Designers play a pivotal role in shaping the products used, consumed and disposed of. Designers in the United States play an even more important role than most other countries in the world due to our unbalanced consumer driven society. Typically, progress related to the environment has been driven by government regulation, public demand, business leaders and managers. There has been slow progress over the past decades; however, this progress can be accelerated if it is addressed from multiple fronts. In other words, sustainability needs to be addressed from the bottom-up as well as from the top-down. A methodology is needed to aid designers with deep convictions to apply sustainable design principles to their work without relying on a mandate from upper management.

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INTRODUCTION

Need for Study

Industrial designers play a pivotal role in shaping the products used, consumed and disposed of. Designers in the US have increased responsibility to other countries in the world. According to the Industrial Designers Society of America (IDSA), the US generates more than 30% of all global warming gases and creates the highest per capita solid waste production of any nation. At the time of publication, it was roughly equivalent to 1500 pounds per person per year. ("Designing")

Scientists believe they can link global warming to the strength of recent hurricanes that have hit the Gulf Coast. Jared Diamond describes reasons for societal failures in *Collapse*. One chapter is dedicated to environmental and resource depletion. (Diamond) It can be argued that you are already seeing the affects of this on the United States and its relationship with countries of the oil rich Middle East.

These are just a few examples of why environmental issues should no longer be the last priority in product design. Typically, in the past, change in regards to the environment has been driven by government regulations, public demand, and upper management. There has been a slow progress over the last two decades; however, this progress can be accelerated if it is addressed on different fronts all with the same ultimate goal in mind--sustainability. As a design consultant, I have found it difficult to address environmental issues. This is due to the fact that our clients do not always share the same convictions towards the environment.

In a survey conducted by the IDSA, designers rated the importance of environmental and human health impacts of products to be roughly twice as important as their clients and managers. The survey points out that designers are able to influence decisions relating to the type of plastic, mix of materials in plastic, ease of disassembly, access to internal components, finish type, form, color, and texture. However, cost analysis was rated twice as important as life cycle analysis as effective information to convince clients and managers about ecodesign attributes. Also, environmental impact was rated the lowest as a product quality priority for products designed, indicating how poorly integrated environmental concerns are in the product development process. (“Electronic” 4)

It is clear that there is a desire on the part of designers to address the environment. However, there is a lack of process integration and cost versus value communication between designer and his or her clients or managers which currently disables designers with conviction to positively affect the environmental issues relating to product development. A methodology is needed to address this disparity. Designer with deep conviction should be able to easily apply ecodesign principles to their work without it being applied as a mandate from upper management.

Objectives of Study

The objective of this thesis is to provide a methodology for individual industrial designers who are proactively pursuing sustainable solutions without a mandate from their company or client. The methodology will likely consist of three main components. The main component will be compilation of design steps that have been proven successful. The second component will be an assessment phase that will guide the designer to the methodological steps that will prove useful to their particular situation. The third step will provide a guideline for how to successfully present the value of sustainable design and how it could apply to the particular design program to managers and/or clients.

Literature Review

Sustainable design is the pursuit of sustainability through design. It bridges many disciplines including architecture, engineering and industrial design. Wikipedia defines sustainability as an attempt to provide the best outcomes for the human and natural environments now and into the indefinite future ("Sustainability").

There are many terms that have been developed over the past decades to describe design that has an environmental focus. The appropriateness of those terms depends on who is asked. Design for environment, ecological design, ecodesign, eco-efficiency design, eco-effective design, green design and sustainable design are examples of such terminology. The general goal for all is essentially consistent. They all refer to design that minimizes the direct and indirect environmental impact where opportunities lie (Lewis, Gertsakis 16). For consistency purposes, this document will standardize on sustainable design unless otherwise directed by the sources and research.

Early pioneers of the environmental movement in regards to industry include Rachel Carson, Buckminster Fuller, and Victor Papenek. Many believe their contribution laid the foundation for the environmental movement of the late 21st century.

With the publication of *Silent Spring* in 1962, Carson presents the argument that pesticides directly contribute to the ill-health of the environment. In a compelling and sobering argument, Carson writes of the millions of years it has taken for the earth to create a balanced ecosystem that supports life and existence as we know it. However, within the century prior to publication, man is the one species in the history of the planet that has acquired the power to alter nature (5-6). Silent Spring contributed to the foundation of the American environmental movement. The book is often praised as one of the most important non-fiction works of the twentieth-century and one of the 25 greatest science books of all-time by the editors of *Discovery* magazine ("Silent Spring").

Buckminster Fuller was a visionary, designer, writer and inventor. Because he worked in so many creative fields, he is often referred to as the "the 20th century Leonardo da Vinci." He popularized the term "spaceship earth" referring to the limited resources of the earth. As a designer, he was one of the first to promote a systems view in relation to the principles of energy and material efficiency ("Buckminster Fuller"). Fuller had great faith in technology's ability to provide for the needs of humanity in an environmentally responsible manner. Another prediction was the unification of the world through the coming of the digital communication age (IDSA "Okala" 8).

Victory Papenek was a designer and educator who didn't shy away from placing blame on the design profession. He called designers "lethal" and those practicing it "murderers." His final literary contribution was *The Green Imperative: Natural Design for the Real World* (IDSA "Okala" 6). In *The Green Imperative,* Papenek reprimands the actions of the past and challenges individuals to rethink their habits and contributions to the "acceleration of disaster". From oil spills to mercury poisoning to the depletion of the ozone layer, he presents examples of irresponsible actions and their direct and indirect effect on the natural and human condition. A fundamental belief of Papenek is: *"Nothing Big Works - Ever!"* (24) He argues that hope for the future relies upon small reversals of the damage caused. Animal species have been brought back from the brink of extinction due to the work of individuals. Beyond criticism, Papenek offers solutions and, as an individual, practiced what he preached. He presents six main categories for designers to address as they design for a safer future: 1. the choice of materials, 2. the manufacturing processes, 3. packaging the product, 4. the finished product, 5. transporting the product, and 6. waste (29-32). Later in this document, these six main categories will show up in many sustainable design strategies including those practiced by environmentally proactive companies.

More recent practitioners and educators of sustainable design include the Industrial Designers Society of America, Helen Lewis, John Gertsakis, Ray Anderson, William McDonough, and Michael Braungart. The most recent strategies presented by this group are discussed in detail later in this document and were likely heavily influenced by the preceding contributions.

Environmental Challenges

The industrial revolution has certainly had a significant impact on the world as we know it, both positive and negative. The industrial revolution provided a means for people of all classes to access comforts once enjoyed only by the rich (McDonough, Braungart 21). However, for all the advances in technology and improvements to the daily lives of many people all over the globe, there are environmental and cultural costs.

In *Cradle to Cradle*, William McDonough and Michael Braungart present a chilling assessment of the current industrial system.

> Consider looking at the industrial revolution of the 19th century and its aftermath as a kind of retroactive design assignment, focusing on some of its unintended, questionable effects. The assignment might sound like this:

Design a system of production that

• Puts billions of pounds of toxic material into the air, water, and soil every year

• Produces some materials so dangerous they will require constant vigilance by future generations

• Results in gigantic amounts of waste

• Puts valuable materials in holes all over the planet, where they can never be retrieved

• Requires thousands of complex regulations to keep people and natural systems from being poisoned too quickly

• Measures productivity by how few people are working?

• Creates prosperity by digging up or cutting down natural resources and then burying or burning them

• Erodes the diversity of species and cultural practices (18)

Cradle to Cradle calls for a "New Industrial Revolution". One in which, at odds with traditional thinking, industry and environment work together to provide sustainable solutions rather than work at odds with one another. In the past, goods and products have followed a cradle to grave process. Behind the industrial revolution was an economic and technological revolution. Industrialists sought out the most efficient ways to bring the greatest number of goods to the greatest number of people. They argue for a closed-loop, or cradle to cradle approach to industry and consumerism, where waste equals food (92).

The cradle to cradle approach has been embraced by many in the business and design communities including Nike, Ford, Herman Miller and Interface Carpets. Ray Anderson, former CEO of Interface Carpets, also calls for the next industrial revolution. After running a carpet company for years with little regard to the environment, Anderson reached an epiphany while reading Paul Hawken's *The Ecology of Commerce.* In Anderson's book, *Mid-Course Correction,* he described himself as a "legal thief" referring to the extraction of finite natural resources as essentially stealing from future generations (7).

Daniel C. Esty and Andrew S. Winston co-authored a book, *Green to Gold*, highlighting the economic motivations for pursuing sustainable design. Although they argue the urgency of particular environmental concerns vary from company to company, they created a list of the top ten environmental issues. They are as follows: 1. Climate Change, 2. Energy, 3. Water, 4. Biodiversity and Land Use, 5. Chemicals, Toxics, and Heavy Metals, 6. Air Pollution, 7. Waste Management, 8. Ozone Layer Depletion, 9. Oceans and Fisheries, and 10. Deforestation. They argue that climate change is not only the top environmental and social issue, but it is also the biggest environmental strategy business has ever faced. The urgency and importance of these issues are non-conclusive and are certainly debatable (32-39). Many of these issues are not isolated issues, but are interconnected. For example, climate change has an enormous impact on biodiversity.

Climate Change

There are many who disagree with mankind's contribution to climate change as well as the importance of addressing it. In recent years, former vice-president Al Gore has likely become the most recognizable face when it comes to global warming and climate change. He has created an award winning documentary and accompanying book, both titled: *An Inconvenient Truth*.

Climate change is caused by greenhouse gasses, such as carbon dioxide, nitrous oxide, and sulfur hexafluoride. These gasses are produced both naturally and by human activity. Greenhouse gasses are responsible for earth's ability to retain heat. They allow light from the sun into the earth's atmosphere and trap a portion of the infrared radiation, which warms the air. Increasing concentration of greenhouse gasses, in part caused by human activity, are trapping more heat and raising the planet's average temperature. This is creating dangerous changes in the climate. Burning of fossil fuels in our cars, factories and power plants releases carbon dioxide. Cutting or burning down forests prevents trees from processing, or reducing, carbon dioxide (28). The United States generates 30% of all global warming gasses (IDSA "Designing").

There are a number of undesired effects of climate change and global warming. In Europe, massive heat-waves killed an estimated 35,000 people in the summer of 2003 (75). The highest average global temperature recorded since the civil war was in 2005. The polar ice caps are melting at a frightening pace (142), increasing the temperature of the oceans and raising sea levels.

Hurricanes are becoming more powerful and more destructive as a result of global warming. The intensity and duration of these storms has increased by about 50 percent since the 1970's. For the first time, there were so many hurricanes and tropical storms in 2005 that the World Meteorological Association ran out of names and resorted to using letters of the Greek alphabet to name the final storms. Two of those storms, Katrina and Rita, both reached category-5 strength and were only three weeks apart (Gore 80-105).

Climate change and human encroachment are both contributors to a mass extinction crisis. The current rate of extinction is now 1,000 times higher than the normal background rate (Gore 163). The destruction of the Amazon rain forest leads to species extinction and simultaneously reduces the number of trees and plants that can process and lessen carbon dioxide in the atmosphere.

Two specific examples of extinction threats include the polar bear and coral reefs. Polar bears are drowning in significant number due to the melting of arctic ice. They must swim longer distances from floe to floe. There are many factors contributing to the death of coral reefs, including pollution, dynamite fishing and more acidic ocean waters. Recent deterioration of coral reefs is believed by scientists to be the result of higher ocean temperatures (Gore 146).

Another threat of global warming is the possibility of a new ice age. Although this seems counterintuitive, scientists are exploring the possibility. If the Gulf Stream were to alter course and not pass through Europe, warmer temperatures carried by the gulf stream would not reach Europe, possibly creating bitter winters similar to those of the "Little Ice Age" in the 17th to 19th centuries (McGuire).

Toxicity and Landfills

Toxicity is the potential of a substance to damage the health of an organism. The majority of substances can be toxic if an organism is exposed to sufficient quantities of the substance. One of the major challenges of toxicity is its persistence to remain in a stable state for a period of time. Toxicity contributes to many environmental damages including ozone depletion, acid rain, water eutrophication, habitat alteration, smog, air pollution, human health damage and ecotoxicity (IDSA "Okala" 19-23).

The United States produces over 200 million tons of garbage every year, the highest per-capita of any nation (IDSA "Designing"). According to the EPA, 57% of that garbage is disposed of in landfills, while 28% is composted or recycled and 15% is burned at combustion facilities. These statistics illustrate the predominantly cradle to grave approach to goods and products. Landfills contain both hazardous and non-hazardous waste. The most common type of landfill restricts exposure to air and water, thereby slowing biodegradation of the waste ("Landfill").

Resource Depletion

Resource depletion is yet another major environmental concern. The four major categories of resource depletion according to Okala are fresh water, minerals, topsoil and fossil fuels. Fresh water consumption typically converts water into non-recoverable forms. Access to clean water is considered a growing international problem. Minerals such as metal ores are converted into metal alloys that eventually oxidize or are dispersed as waste. Topsoil is being eroded by agriculture faster than natural processes can replenish it (IDSA "Okala" 16).

It takes nature a million times longer to replenish the fossil fuel reservoirs than the current rate of consumption (IDSA "Okala" 16). There comes a point when a finite resource such as oil becomes more expensive to extract and less is extracted. The term for that point is production peak, or as many have termed it in this case "peak oil." (Steffen 74) Experts argue over when that peak will come, but it is essential to address the issue considering our culture is "addicted to oil."

Oil is used for a number of applications other than fueling our cars, factories and power plants. It is also used in the production of most plastics. Plastics consume around 80 million tons of the output from crude-oil refineries in the Untied States alone (Gengross, Slater).

Geopolitics and national security are other issues adding to the complexity of the limited oil supply. The need for oil around the world aids the instability of international politics. Thomas Freedman has been relentlessly promoting the green movement recently. The following excerpt is from an article that appeared in the *New York Times Magazine*. "The biggest threat to America and its values today is not communism, authoritarianism or Islamism. It's petrolism. Petrolism is my term for the corrupting, anti-democratic governing practices - in oil states from Russia to Nigeria and Iran - that result from a long run of $60-a-barrel oil. Petrolism is the politics of using oil income to buy off one's citizens with subsidies and government jobs, using oil and gas exports to intimidate or buy off one's enemies, and using oil profits to build up one's internal security forces and army to keep oneself ensconced in power, without any transparency or checks and balances." (Freedman "Green")

Trends in Sustainable Design

There are a great many trends relating to sustainable design. Public awareness, government regulation, and need are driving many of the trends described below. They range in scope from progressive sustainable business models to technological break-throughs. Even Wal-Mart, negatively viewed by many as an evil corporation, may prove to be a great catalyst for change. It will take a cohesive effort on many fronts to address the many issues related to a sustainable world.

Government Regulation

Looking at the challenges from the top-down, the first place to start is with man-dated government regulation. As of 2006, 169 countries and other government entities had ratified the Kyoto Protocol agreement, with the objective to stabilize "greenhouse gas concentration in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system." (http://en.wikipedia.org/wiki/Kyoto_Protocol) The Bush administration opted out of the agreement, saying it would have "wrecked" the United States economy as recently as 2005 (Associated Press "Bush"). In what is per-ceived as a progressive step towards addressing climate change, in June of 2007, leaders of the eight largest industrialized nations, including the United States, agreed to "sub-stantial" cuts in greenhouse gas emission. Although this may be a positive turn of events, this agreement set no binding targets for the restrictions.

Likely the most progressive and expansive government directives is concerning the Restriction of Hazardous Substances Directive (ROHS). Another is the Waste Electrical and Electronic Equipment Directive (WEEE). In combination, the directives impose responsibility to manufacturers to restrict hazardous substances and dispose of the product. ROHS restricts the use of lead, mercury, cadmium, hexavalent chromium, polybrominate biphenyls and polubrominate diphenyl ether ("Restriction"). WEEE imposes the responsibility to provide users of electrical and electronic equipment the possibility of returning those products at least free of charge. It also compels companies to utilize the collected waste in an ecologically-friendly manner ("Waste").

Due to the lack of leadership on the federal level in the United States, state and local governments are taking it upon themselves to legislate environmental policy. Under an executive order signed on June 1, 2005 by Governor Arnold Schwarzenegger, California has established its own greenhouse gas targets that include reducing emissions to the 2000 level by 2010, reducing emissions to the 1990 level by 2020, and a reduction of 80 percent below the 1990 level by 2050 ("Climate").

Many city governments are following in step. For example, New York is planning to upgrade its city taxis to emit less exhaust. Likewise, Decatur, Georgia has a number of green initiatives including low-emission vehicles, all-natural cleaning supplies, compostable office supplies, and corn-based coffee cups. (MacDonald B1)

Ultimately, it is the responsibility of the citizens of a democratic nation to determine the direction of the government. Citizens must demand transparency in government, elect the best politicians available, and hold those leaders who do wrong accountable (Steffen 409).

In a shrinking global world, the international community can also prove to be a catalyst for change. Geopolitics can play a dramatic role in shaping environmental policy. Many critics of the Iraq war see it as an attempt to stabilize oil supplies. Those same critics believe America has lost much of its credibility over the past few years as a result of its environmental and foreign policy including the invasion of Iraq. In an April 2007 column entitled *The Power of Green*, Thomas Freedman argued one way "to reknit America at home, reconnect America abroad and restore America to its natural place in the global order -- as the beacon of progress, hope and inspiration," was to "green" America. He continued with the following excerpt,

> Well, I want to rename "green." I want to rename it geostrategic, geoeconomic, capitalistic and patriotic. I want to do that because I think that living, working, designing, manufacturing and projecting America in a green way can be the basis of a new unifying political movement for the 21st century. A redefined, broader and more muscular green ideology is not meant to trump the traditional Republican and Democratic agendas but rather to bridge them when it comes to addressing the three major issues facing every American today: jobs, temperature and terrorism. (Friedman "The Power" 1)

Alternative Energy

As described above, oil and other fossil fuels are major contributors to environmental challenges. Redefining our energy infrastructure is a major focus area for governments, businesses and the individual. Switching to clean and renewable energy sources can go a long way towards addressing environmental sustainability.

Most of the citizens of the United States rely on the power grid. Electricity is supplied by power plants. Those power plants burn coal or oil or use nuclear radiation. (Steffen 170). For most, that means that turning on the lights, recharging batteries, or turning on the air conditioner is a contribution to global warming. In relation to product design, the energy consumed in the extraction of materials, manufacture and use of products is pulling energy off the fossil fuel powered grid. The cost of alternatives in relation to energy generated by fossil fuels is surprisingly competitive and will only continue to decrease in relative cost as coal and oil become more rare and the alternative energy technology improves. Three promising clean energy alternatives are solar power, wind power, and tidal power (Steffen 170-177).

Though clouds, shade and nighttime are enemies to solar power, drawing energy from the sun is a great renewable resource. The two main types of solar energy are solar-thermal systems and photovoltaic-cell (PV) systems. Solar-thermal systems collect radiant energy to produce heat. Photovoltaic systems are still fairly expensive and mostly used in off-grid applications. That may change as new materials are developed. There is also opportunity to use flexible thin-film and organic-plastic solar panes in applications including building materials, and energy-producing laptop bags and backpacks (Steffen 172-174).

Nanotechnology researchers are also working on multiple solar projects. One in particular is a composite that can be sprayed onto other materials. The result could allow a sweater coated with the material to power a cell phone or wireless device. The researchers also envision a “solar farm” made up of the plastic material that could be rolled across deserts to generate an entire plant’s power needs (Lovgren).

Another visionary solar project is solar satellite power (SSP). Essentially, satellites orbiting the earth can gather sunlight, convert it to electricity, and beam the energy to earth using microwaves. The positive attribute to this technology is that it is above earth’s atmosphere and therefore not subject to the loss of energy due to clouds. The microwaves will heat the atmosphere slightly and the frequency must be chosen carefully as to not cook birds (Globus).

Wind power is another alternative energy source and may be the cleanest. The U.S. Department of Energy has concluded that the world’s current energy usage is one fifteenth of the amount of energy that could be generated by the world’s winds. As more wind farms are being built, the price is dropping to compete with oil and coal. This economic factor of wind power should ultimately encourage the construction of more wind farms (Steffen 174-176).

Tidal Power is a third clean energy alternative. Systems are only now beginning to be developed; however, the potential to generate power through the motion of water is great. Currently, it is not viewed as clean an alternative as wind (Steffen 177).

Ecomaterials

Materials selection has traditionally been based on the physical, chemical and aesthetic properties of the material, as well as the materials' cost and availability. Environmental parameters, such as resource depletion, are now proving more important (Fuad-Luke 282). The increased importance placed on the environmental aspect of material has compelled chemists and other material engineers and suppliers to pursue alternatives. Scientists are now mimicking the process used to derive polymer chains from oil. By replacing oil with corn starches, they have created a new polymer called polyactic acid (PLA) (DemirJian). PLA is just one example of an ecomaterial being developed as an alternative to traditional plastics and is not without its problems.

Ecomaterials are materials that are easily reintroduced to closed-loop cycles. They have minimal impact on the environment while offering maximum performance for the required task (Fuad-Luke 282). An ecomaterial is better than a non-ecomaterial, at least in theory. It must be used correctly to avoid creating a far worse scenario. For example, PLA can be used instead of PET/PETE, a recyclable plastic. However, if not discarded correctly, a small amount of PLA mixed in with PET/PETE can contaminate and entire batch of recyclable material, rendering that batch unsuitable for recycling (Jedicka).

By taking the cradle to cradle approach as outlined by McDonough and Braungart, the only way to avoid a cradle to grave scenario is that materials must be selected that are either biological or technical nutrients.

> Products can be composed either of materials that biodegrade and become food for biological cycles, or of technical materials that stay in

> closed-loop technical cycles, in which they continually circulate as valuable nutrients for industry. In order for these two metabolisms to remain healthy, valuable, and successful, great care must be taken to avoid contamination one with the other. Things that go into the organic metabolism must not contain mutagens, carcinogens, persistent toxins, or other substances that accumulate in natural systems to damaging effect. By the same token, biological nutrients are not designed to be fed into the technical metabolism, where they would not only be lost to the biosphere but would weaken the quality of technical materials or make their retrieval and reuse more complicated (104-105).

A biological nutrient is a material taken from the biosphere that is designed to be returned to the biological cycle, consumed by microorganisms and other animals. Biosphere materials include compost-able biopolymers and biocomposites. On the other hand, a technical nutrient is a synthetic material that is designed to be returned to technical cycles. Many of them are derived from fossil fuels and require much more energy to be processed (Faud-Luke 282).

New ecomaterials are being developed constantly, including paints and varnishes, boards and composites, textiles, and biopolymers (Fuad-Luke 282-301).

Standards and Practice

There are standards and certifications that can add legitimacy to claims of environmental improvements to products and building. By meeting these standards and certifications, businesses can market their products in a way that consumers appreciate.

Energy Star

Energy Star is a government-aided program helping businesses and individuals protect the environment through superior energy efficiency. It began in 1992 when the EPA introduced it as a voluntary labeling program designed to identify and promote energy efficient products to reduce greenhouse gas emissions. Computers and computer monitors were the first products that began to use the labeling. As the benefits became more apparent, Energy Star branched out into other industries including major appliances, office equipment, lighting, home electronics, new homes and commercial and industrial buildings. Energy Star participates in over 50 product categories. In 2006 alone, Energy Star delivered energy and cost savings across the country, saving businesses, organizations and consumers about $14 billion (Energy Star "History").

ISO Standards

"The ISO 14000 series stresses the importance of product-oriented objectives and supportive tools (e.g. Life Cycle Assessment (LCA) and environmental labeling.) It may therefore be expected that implementation of the ISO 14000 series provide a good framework for environmental product improvements." (Cramer 8)

ISO 14000 refers to a series of voluntary standards in the environmental field under development by ISO (International Organization for Standardization). The ISO standards are international and therefore avoid conflicting and inconsistent national and regional standards. ISO 14001 specifies a framework of control for an Environmental Management System against which a company or organization can be certified by a third party. It is the cornerstone of the ISO 14000 series of standards (ISO 14000).

Cradle to Cradle Protocol

The MBDC is a product and industrial process design firm that has developed what they call a new paradigm in design, The Cradle to Cradle Protocol. William McDonough, an architect, and Michael Braungart, a chemist, were both actively working as advocates of sustainable design before coming together to found the MBDC. They have worked with the following companies, providing consultation while pushing the Cradle to Cradle Design process: BASF, BP, S.C. Johnson, Nike, Ford Motor Company, Visteon, Volvo, Herman Miller, Victor Innovatex, Design-tex, Rohner Textil, Pendleton, and Milliken & Co. (MBDC "Client").

Cradle to Cradle Design is a fundamental conceptual shift away from the flawed system design of the Industrial Revolution. Instead of designing products and systems based on the take-make-waste model of the last century 'cradle to grave', MBDC's Cradle to Cradle Design paradigm is powering the Next Industrial Revolution, in which products and services are designed based on patterns found in nature, eliminating the concept of waste entirely and creating an abundance that is healthy and sustaining. Eco-Effectiveness is MBDC's design strategy for realizing these results by optimizing materials to be food either for nature's ecosystems or for humans' industrial systems--perpetually circulating in closed systems that create value and are inherently healthy and safe (MBDC "Eco-Effectiveness").

One of the tools of the Cradle to Cradle protocol is to label materials as green, yellow, orange and red according to human health and environmental relevance criteria. Green materials qualify as little or no risk and are encouraged while red materials have high risk and are to be phased out as soon as possible (MBDC "The Cradle").

The protocol is a rare private certification, so it is able to maintain and control high standards. For example, a Cradle to Cradle platinum rating cannot be applied to an office chair unless the chair avoids poisons and the workers who made the chair are paid and treated well (Steffen 116).

LEEDS

The US Green Building Council has developed a LEEDS certification for buildings that meet certain green standards. The "Green Architecture" movement has been successful. A local program aligned with the green architecture movement is the Auburn University Rural Studio Program, where students are taught and encouraged to use recycled materials while also helping one of the poorest counties in the nation (USGBC).

There are inherent differences in architecture and industrial design, however, that make sustainable architecture more appealing to upper management and decision makers who have their eyes on the bottom line. Green buildings may cost more to build initially, but they are designed to be energy efficient and ultimately save money in the long run.

Although reducing energy consumption is a universal goal of sustainability, it is difficult to simply apply the same justification to mass-produced products.

Changing Business Environment

In *Green to Gold*, authors Esty and Winston argue that "climate change is shaping up to be the biggest environmental strategy issue the business world has ever faced." (39) Consumer demand, government regulation, competitive pressure, resource depletion, and profit opportunity are some of the factors leading to a shift in the perception of environmental initiatives within the business community.

Consumer Willingness and Demand

According to *WorldChanging*, designers can't keep pace with the increasing consumer demand for truly environmentally friendly products (Steffen 84). A slight minority of all Americans, 42%, are willing to spend more money for products branded as organic or environmentally friendly. Half of those 18-29 years of age are willing to spend more, while 37% of 45-64 year old consumers say they will spend more on green products (GreenBiz.com). Additionally, half of all Americans say they would do more for the environment if they knew how. This provides great motivation for businesses to use green products and marketing to educate consumers (Ottman).

Access to cheaper raw materials and lower capital, traditional elements of competitive advantage have whittled away in the increasingly global economy. The changing competitive environment makes room for environmentally friendly products to add enduring value to the consumer and create a competitive advantage. Phil Berry of Nike describes it as follows: "We have two maxims. Number 1: It is our nature to innovate.

Number 2: Do the right thing, But everything we do around sustainability is really about number one - it's about innovations" (Esty, Winston 11-12).

Toyota was unable to anticipate the success of the Prius, a gas-electric hybrid vehicle. In 2004, after Toyota spent a decade researching and developing the Prius, it was named Motor Trend's Car of the Year. The demand was so great that there was a six-month waiting list to receive a new Prius. The Prius may be the first major consumer product to represent "green" without compromise. It is from a trusted company, it doesn't require customers to change their habits, and it can actually save the consumer money. In another example of a company trying to relay to customers its environmental consciousness, BP recently re-branded itself as "Beyond Petroleum" and began investing in renewable energy (Esty, Winston 10-11).

The Bottom Line

Another motivation for business to pursue sustainable design is the bottom line of the balance sheet. Cutting cost and avoiding the adverse effects of an environmental catastrophe are two such examples. Eco-efficiency is often used to describe business efforts to cut waste and reduce resource use. The effects can save money that almost immediately drops the bottom line. If a business redesigns a process that uses less energy, it can reduce its exposure to unstable oil and gas prices. If a business eliminates toxic substances from its product, it can cut regulatory burdens and reduce its exposure to a value destroying incident in the future (Esty, Winston 13).

The internet is providing an unprecedented level of transparency that is transforming the business world. Anything that goes wrong within a company or in supplier

operations can hit the web almost instantly with bloggers everywhere, including inside the company. Warren Buffett once said, "It takes twenty years to build a reputation and five minutes to ruin it. If you think about that, you'll do things differently."
(Esty, Winston 17)

There have been two recent catastrophic examples of products containing toxins. Major pet food suppliers in North America recalled their products because they caused the death of at least 16 cats and dogs. The source of the toxic chemical was traced to a small agricultural products trader in Xuzhou, China (Barboza). Without an effective quality control system in place to catch such toxins from their suppliers, the companies involved had to absorb costs associated with of one of the biggest pet food recalls in history as well as the damage to their image.

Another example of dangerous levels of toxicity showing up in products was a recent recall by Wal-Mart of baby bibs laced with high levels of lead. The lead levels exceeded levels set by Illinois for children's products (Associated Press "Wal-Mart").

As a sign of how important environmental issues have become in the business world, a new set of stake-holders, including banks and insurance companies, has arrived on the environmental scene. "When the financial services industry - which focuses like a laser on return on investment - starts worrying about the environment, you know something big is happening." (Esty, Winston 9) Esty and Winston attempted to compare stock performances of environmentally focused companies in relation to the rest of the market in *Green to Gold*. They examined environmental and sustainability scorecards by the analysts at Innovest Strategic Value Advisors, Sustainable Asset Management, and others in the field of socially responsible investing. Esty and Winston called the list of leaders “Wave Riders.” The comparison indicated that Wave Riders outperformed the major indices over the last ten years (24-27).

Environmental Leaders

Although the following is just a sample of environmentally progressive companies, there are lessons to be learned from all of them. They share many of the same sustainable strategies, but each approach sustainability in their own way. They also serve as inspiring examples that environmental initiatives can increase brand loyalty, profitability, and put pressure on suppliers and their competitors to follow suit.

Herman Miller

Herman Miller is recognized as one of the leaders in the area of sustainable design. They have been successful, in part, thanks to the creation of the Environmental Quality Action Team (EQAT), an internal group focused on the environment. The EQAT is further broken down into several support teams: the Communications Team, Design for the Environment Team, Environmental Affairs Team, Green Buildings Team and the Environmental Low Impact Processing group. Each team is responsible for separate actions that pursue the EQAT’s overall goal: “Journey towards sustainability”.

The company has set 2020 as a year to completely eliminate VOC emissions, water emissions and hazardous waste. In 1991, they had 41,000,000 pounds of waste, 5,200,000 lbs. in 2003 and plan to eliminate all waste by 2020. Additional accomplishments include:

- From 1992 to 2001, Herman Miller avoided $700,000 in annual energy costs by participating in the Environmental Protection Agency's Energy Star Building program. a 33.5% ROI.
- We are the second largest purchaser of green power in the State of Michigan.
- We have reduced greenhouse gas emissions by 7,000 tons annually since 2001.
- In 2003, we completed converting the last metal we-coat paint line to powder, reducing Volatile Organic Compounds (VOCs) by 67%, even though we had already met the new EPA Hazardous Air Pollutant Emission requirements.
- Since 1995, we have eliminated 50% of packaging materials by blanket and stretch wrapping products shipped.
- 90% of packaging between Herman Miller and our suppliers is reusable.
- After a 10-year effort, we won approval from Michigan's Department of Environmental Quality to have our sawdust mixed with chicken manure, composted, and returned to the environment as a high-grade topsoil and nutrient (Herman Miller).

The Design for the Environment Team is the one most closely related to industrial design. As with most companies that pursue sustainable design, they incorporate it in the earliest stages of product development. It has adopted the MBDC Cradle to Cradle

Design Protocol as discussed earlier. The main areas of focus as discussed on their website are:

- Material Chemistry and Safety Inputs - What chemicals are in the materials we specify, and are they the safest available?
- Disassembly - Can we take products apart at the end of their useful life to recycle their materials?
- Recyclability - Do the materials contain recycled content, and more importantly, can the materials be recycled at the end of the product's useful life (Herman Miller)?

All future products developed by Herman Miller will be evaluated by the MBDC Cradle to Cradle Design Protocol. Most recently, some of their success stories relating to sustainable design are Kira textile which is made from corn and is completely compostable and the Mirra Chair. The Mirra Chair can be disassembled in 15 minutes and 96% of it is recyclable. Their dedication to respecting and protecting the natural environment will be balanced with their dedication to create great working environments (Herman Miller).

Philips

Philips (Royal Philips Electronics) has developed a comprehensive environmental responsibility program. There are several layers to their program. "EcoVision" is the umbrella program. "EcoDesign" focused on five areas when developing products: weight, hazardous substances, packaging, recycling and disposal, and energy consumption (Philips "EcoDesign"). Each of the five areas has color coded symbols for communication purposes. Philips believes strongly in educating all of their work force on environmental related issues. They produce a manual on environmental-oriented product development for their designers (Cramer 10).

In their 2004 sustainability report, they disclosed that 21 new products earned their internal Green Flagship status. That number is up from eight the previous year. They have introduced over 100 flagship products in total. Philips' Green Flagship products offer a better environmental performance than their predecessors or closest commercial competitors in the Green Focal Areas mentioned above.

Philips does not just focus internally on the environment, but they also work with their suppliers. A select group of key suppliers have agreed to the Supplier Declaration on Sustainability, which related directly to their internal principles. They also have trained 400 assessors to audit the supplier program and make sure that the suppliers are living up to their agreement.

"We continue to be dedicated to sustainability, to finding the proper balance between the sometimes-competing demands of integrating social, environmental and economic responsibility. To do that, we are working to embed sustainability thinking in all of our day-to-day operations. This is our philosophy and a cornerstone in the strategy we have chosen to pursue."

One of the Green Flagships in 2004 is the Philips Medical Systems' iU22 ultrasound system for the next generation, real-time 4D imaging. In comparing the system to its predecessor, the iU22 weighs 22% less, eliminates 82% of the hazardous substance mercury, reduces energy consumption by 37%, uses 20% less packaging, and offers a 30% improvement in total weight of recyclable material (Philips "Philips Publishes").

Xerox

In 1991, Xerox created the Environment, Health, and Safety policy. It has since been divided into five categories: Safe Workplace and Healthy Workplace, Waste Free Facilities, Safe Products, Accessible Products and Waste-Free Products. The Waste-Free Products category is responsible for diverting 1.5 billion pounds of waste from landfills since 1991 by following end-of-life strategies. They have reduced product energy consumption by up to 50% since 1992. Adding product features such as duplex copying and printing have helped customers be more efficient with their use of paper. In 2003, 97% of all new products had duplex printing capabilities.

Similar to Philips, Xerox conforms to ISO 14000 standards and extends its environmental, health and safety requirements across its supply chain. They apply additional requirements to their paper suppliers. Xerox places additional importance on design for reuse. Many of their products share the same components and are designed for quick disassembly. All products introduced since 2003 were designed with remanufacture in mind. This gives Xerox multiple options for returned equipment. The reused parts can be remanufactured into machines of the same type, manufactured into machines in the same product family or used in the development of future models. This is successful, in part, due to leasing agreements Xerox has with a significant portion of its clients (Xerox)

Interface

Ray C. Anderson is the founder and former CEO of interface. Interface is considered a world leader in sustainability. In 1994, he was running one of the world largest interior supply businesses when he came to a rude awakening. He realized what he and the rest of the industrial world were doing to the environment. By his own words, he was a "legal thief." He was taking the earth's capital that belonged to everyone of every generation and putting the burden of the expense on future generations (Anderson 7).

When he gives speeches he often begins the speech by asking everyone in the audience to stand and hug other members of the audience and explains the reason for this in his opening statement: "I hope the symbolism of that was not lost on you, fellow astronauts on Spaceship Earth. We have only one spaceship. It's in trouble. We're in this together and need each other." (Anderson 1)

Inspired, in part by McDonough, he is focused on creating the Next Industrial Revolution while disagreeing to some degree with those who say we've already made it to the second (electricity powered) or third (information age) Industrial Revolution.

> However, I take the view that they all share some fundamental characteristics that lump them together with an overarching, common theme. They were and remain an unsustainable phase in civilization's development. For example, someone still has to manufacture your 10 pound laptop computer, that icon of the information age. On an "all-in" basis, counting everything processed and distilled into those 10 pounds, it weighs as much as 40,000 pounds, and its manufacturers, going all the way back to the mines (for materials) and wellheads (for energy), created huge abuse to the Earth

through extractive and polluting processes to make it. Not much has changes over the years except the sophistication of the finished product (Anderson 9) .

Anderson realized that it would take a revolutionary business model to right the wrong. His ultimate goal is to create an influential company that was restorative. He defines restorative as giving more back than what is taken, to do good to Earth, not just to avoid harm. He avidly believes that a business approach with this in mind can lead to higher profits. Interface has achieved higher profits while continuing to develop a restorative business model. For example, in the first three years of this effort, Interface was able to reduce waste by 40% and saved $67 million (InterfaceFLOR).

Interface's sustainability program includes seven fronts.

1. Eliminate Waste -Through certain product lines, Interface works to eliminate waste. This has two design features that enable this. One is that the tiles are modular and can be infinitely adaptable. They have the capability to be installed and replaced randomly. They are also designed with natural patterning, which almost eliminates installation waste and make it easy to repair, adapt and reuse.
2. Eliminate Harmful Emissions -This front focuses on the environmental aspects to the manufacture of the carpet tiles. It works to offset any greenhouse gas emissions that result throughout a carpet's life cycle.
3. Use Only Renewable Energy -Interface continues to rely less upon non-renewable energy. For example, it uses photovoltaic (PV) panels to

power portions of its manufacturing facilities. At its LaGrange, GA carpet facility, a PV array generates electricity equivalent to that needed to power one loom.

4. Create Closed Loop Processes -Interface describes the recycling of their products as “mining”. Interface actively “mines” discarded flooring materials to manufacture its recycled vinyl backing, taking responsibility for others’ abandoned products, and giving new life to old resources.
5. Minimize Moving People and Material -By participating in the Trees for Travel program, Interface plants one tree for every 2000 miles of employee air travel. This helps mitigate fuel emissions. They also attempt to reduce travel by employees. They describe the electronic transfer of designs as “shipping”. They “ship” designs to manufacturing points worldwide.
6. Integrate Sustainability into Our Culture -Three-quarters of Interface Flooring Systems employees have been trained in sustainability principals. A workforce focused on the efficient use of financial, environmental, and human capital becomes an advocate for the sustainability of our customers’ floor-covering investments.
7. Pioneer New Business Models of Sustainability -The Interface reclamation program evaluates and processes used carpet. They reuse, repurpose

and recycle their flooring as well as that of competitors. They guarantee that your carpet will not end up in a landfill if they reclaim it (Interface-FLOR).

Nike

Nike is another environmentally progressive company with a long term sustainable focus ranging from eliminating toxins to regrinding shoes for reuse in sports surfaces. The key focus areas as defined by Nike's environmental strategy are to promote compliance with environmental standards set by Nike and others, to eliminate waste and toxics across the product lifecycle, to build their corporate ability to utilize sustainable material platforms, to reduce the environmental footprint of packaging and shipping their products, and to implement innovative programs that turn waste into business opportunities.

Nike has created internal Restricted Substances Lists that are predominantly based on the most stringent worldwide legislation. They are working to ensure that restricted substances are not used in Nike products. Their goal is to work with the scientific community, stockholders, and their supply chain to go above and beyond regulatory compliance.

They continue to build their ability to use four key sustainable material platforms. Organic cotton is an example of a material that is grown without the use of synthetic chemical pesticides, fertilizers or defoliants. The second strategy is to use materials determined to contain significantly lower amounts of chemicals they deemed to be of concern. An example of this is environmentally preferred rubber, which they have managed to eliminate 96% of the identified chemicals from one of the highest volume rubber formulations. The third is to use reprocessed materials or products that can be converted to new products such as closed loop materials. Fourth, they will incorporate renewable, plant-based raw materials that can be used to manufacture natural or bio-based textile fibers and polymers, such as PLA.

One unique program Nike has instituted is their Reuse-A-Shoe program, which is set up to collect shoes of any brand not containing metal from consumers. The collection sites are now located within 15 miles of 32% of the population. Once collected, the shoes are ground into three components called Nike Grind. The three varieties are upper fabric, mid-sole foam, and out-sole rubber. Over 15 million pairs have been processed for recycling. Nike Grind is used in conjunction with other materials to create sports surfaces for soccer, football, baseball, basketball, tennis, running tracks and playgrounds
(Nike 56-73).

Wal-Mart

By shifting focus more towards the environment, Wal-Mart's new initiatives have the power to significantly change the priorities of not just Wal-Mart, but the great many companies that supply products to the retailer. The three main goals focused on sustainability are: 1. to be supplied by 100% of renewable energy, 2. to create zero waste, and 3. to sell products that sustain our resource and environment. The new initiatives came out of a company-wide, long-term initiative to unlock their potential. The company formed entrepreneurial teams, who worked with environmental consultants, non-profit organizations, and other groups, focused on areas such as packaging, real estate, energy, raw materials, and electronic waste (Wal-Mart "Overview").

The first of the three goals, the renewable energy initiative, is working to make existing stores 25% more efficient over the next seven years, while making new stores 30% more efficient in a shorter timeframe, four years. Strategies include experimental stores that use solar and wind power, testing zero-emission forklifts, replacing incandescent lights bulbs with compact fluorescent light bulbs, replacing fluorescent lighting in their refrigerated cases with LED lighting, and adding hybrid cars to their corporate fleet (Wal-Mart “Renewable Energy”).

In a move towards zero waste, they aim to reduce solid waste by 25% over the next three years and are pushing to have all private brand packaging improved over the next two years. Specific strategies include the use of corn based plastic (PLA) for some fruit and herb containers, reducing material in Sam’s choice water bottles, replacing non-recyclable wax-coated boxes with more sustainable recyclable boxes, improving the packaging on a line of Kid Connection toys, creating a home office recycling program, and asking suppliers to consider more sustainable packaging (Wal-Mart “Waste Reduction”).

Wal-Mart has over 65,000 suppliers. To achieve their sustainability goals, Wal-Mart knows that those who supply their products must be in line with the same or similar goals. They are constantly learning new ways to encourage suppliers to do so. One way is by creating an incentive plans and common-sense scorecards for their merchandise buyers that encourage innovation and more environmentally friendly products (Wal-Mart “Sustainable Products”).

Product Development Strategies

The following are examples of sustainable strategies, tools, checklists and methodologies developed in recent years focusing on product design and development. They range in scope and definition, and the strategies are often a list of issues that can be addressed before, during, and after the product development process. The following summary of two strategies will show that there are many similarities and they build on one another.

Design + Environment

Helen Lewis and John Gertsakis co-authored *Design + Environment*, a comprehensive guide intended to help product developers design greener products. They argue that many significant environmental improvements can be realized through the use of basic checklists and general rules of thumb. Their book provides such checklists. The five main categories outlined in *Design + Environment* are: 1. Select low-impact materials, 2. Avoid hazardous materials, 3. Choose cleaner production processes, 4. Maximize energy and water efficiencies, and 5. Design for waist minimization. These strategies are first discussed in detail and then applied to specific industries including packaging, furniture and electronics (61-94).

Select Low-Impact Materials

With regard to the environment, there is no clear hierarchy of materials. Materials can be evaluated in reference to a variety of criteria, including the source, process, additives, energy efficiency, durability, and recyclability. Designers should pursue four goals when selecting materials.

- Choose abundant materials free of toxins when possible.
- Choose natural materials over synthetic materials when possible.
- Minimize material use.
- Choose recycled materials when possible.

The remainder of the materials selection section of *Design + Environment* serves as a good reference for materials including plastics, timber, glass, aluminum, steel, and paper it provides charts and graphs explaining the life-cycle and energy consumption of some of these (61-76).

Avoid Hazardous Materials

The second general strategy discussed in the book is to avoid hazardous materials. An appendix provides a list of hazardous materials that should be eliminated or minimized if possible. The four-point checklist provided by the authors is listed below.

- Avoid materials that are toxic to humans or other living organisms.
- Avoid materials that are flammable, explosive or corrosive.
- Avoid materials that are ozone-depleting.
- Avoid materials that contribute to global warming (Lewis, Gertsakis 76-79).

Choose Cleaner Production Processes

Strategy category three encourages designers to choose cleaner production processes. Cleaner production processes are described as those with minimal waste, including liquid waste, solid waste and waste discharged to the air. By evaluating the lifecycle of products or materials can provide insight into which processes should be avoided. The two steps suggested by Lewis and Gertsakis are:

- Designers should work with production staff to select materials and/or processes that are less wasteful.
- Designers should work with purchasing staff to identify suppliers that meet 'industry best practice' in cleaner production

They go on to give examples of industries including the footwear and automotive industries that have pursued such initiates as well as some strategies for reducing industrial waste (Lewis, Gertsakis 80-81).

Maximize Water and Energy Efficiencies

Maximizing the use of resources such as water and energy will reduce the environmental impact of the product during use, which oftentimes is more significant than the production or disposal of the product. The three main strategies detailed in this section are:

- Design for energy efficiency.
- Use cleaner energy sources.
- Design for water efficiency.

The industrial designer may not have much influence over this category, but there are a few key points that the designer may influence. If possible the designer should review this section with other key team members and make suggestions. With regard to water efficiency, a designer should be on the lookout for any leaks which would lead to water inefficiency. If a product is powered by a battery, a designer can suggest or encourage the use of rechargeable batteries, which due to their life-span are typically considered cleaner than non-rechargeable. When working with the user-interface of a product, a designer can specify a default mechanism that automatically resets the appliance to its most efficient setting, as well as specifying a means to provide feedback as to how much energy or water is being consumed (Lewis, Gertsakis 81-86).

Design for Waste Minimization

The final general strategy presented in *Design + Environment* is to design for waste minimization. It is important to minimize the amount of material or substance entering the waste-stream. Industry is beginning to take cues from nature where waste from one process or product is used as the raw material for another. Although the infrastructure for this to take place is not fully realized, it is important for the designer to be proactive when possible. The following strategies are discussed by the authors in more detail (61-94).

- Design for source reduction.
- Extend the product life.
- Design for product reuse.
- Design for product remanufacture.
- Design for material recycling.
- Design for minimal consumption.
- Minimize the impacts of disposal (86-94).

Okala

Okala is an introductory curriculum developed for product design students by the IDSA. The Hopi are among the most ancient of Native American cultures, and in their indigenous language, the term Okala means "life sustaining energy." Although it was developed as an introductory curriculum, it is more comprehensive and in-depth than the other resources provided by the IDSA on their ecodesign interest section website. It was co-developed by Philip White, Louise St. Pierre and Steve Belletire in partnership with Eastman Chemical and Whirlpool with the support of IDSA/EPA Partnership.

The *Okala Course Guide* describes the general needs for industrial designers to address sustainability including a brief evolution of the biosphere, principles of ecology, and the environmental impact of products. It also attempts to provide a general education on toxicity and lifecycle assessment. Most importantly, there is the guide for pursuing environmental strategies is called the “Ecodesign Strategy Wheel.”

The strategy wheel consists of seven strategic categories arranged around a circle. “The beginning of the cycle refers to the creative inception of the product: design for innovation. Continuing clockwise, design decisions such as material choices, manufacturing and distribution, the use phase, length of life and end of life are all arranged sequentially.” (34) The seven key categories are listed below as well as the more specific strategies that fall under the main categories.

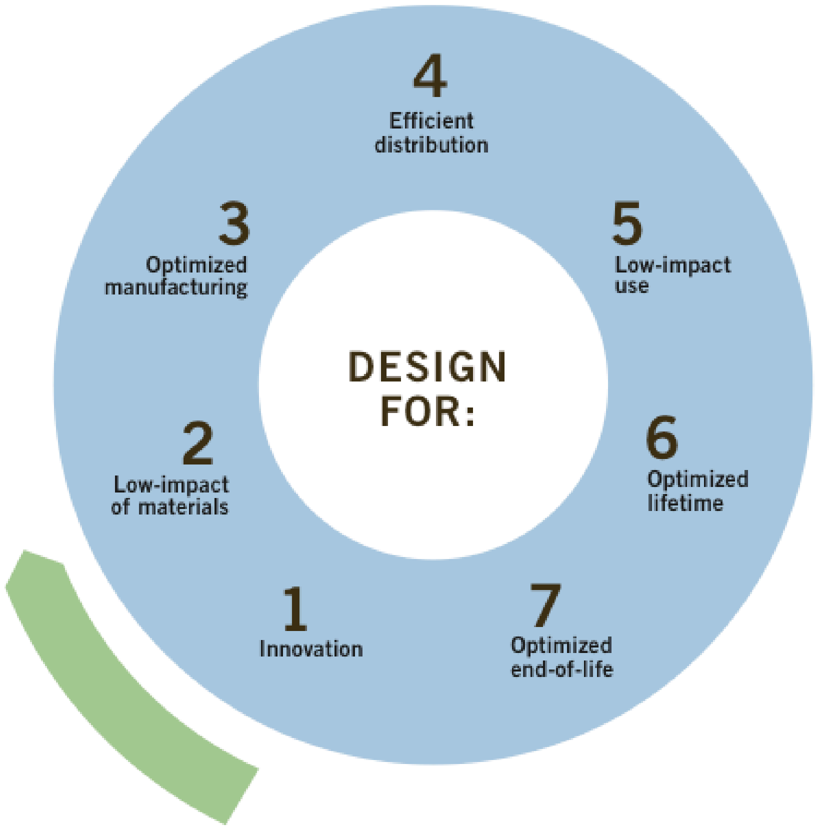

Figure 1: Okala Ecodesign Strategy Wheel

1. Design for innovation.
    - Rethink how to provide the benefit.
    - Provide needs provided by associated products.
    - Anticipate technological change and build in flexibility.
    - Design to mimic nature.
    - Use living organisms in product.
2. Design for low-impact materials.

- Avoid materials that damage human health, ecological health, or depletion resources.
- Use minimal materials.
- Use renewable resources.
- Use waste byproducts.
- Use thoroughly tested materials.
- Use recycled or reused materials.

3. Design for Optimized manufacturing.
    - Design for ease of production quality.
    - Minimize manufacturing waste.
    - Minimize energy in production.
    - Minimize number of production operations.
    - Minimize number of components/materials.
4. Design for efficient distribution.
    - Reduce product and packaging weight.
    - Use reusable or recyclable packaging.
    - Use an efficient transport system.
    - Use local production and assembly.
5. Design for low-impact use.
    - Minimize emissions/integrate cleaner or renewable energy sources.
    - Reduce energy inefficiencies.
    - Reduce water use inefficiencies.

- Reduce material use inefficiencies.

6. Design for optimized product lifetime.
    - Build in user's desire to care for product long term.
    - Design for ease of product take-back programs.
    - Build in durability.
    - Design for maintenance and easy repair.
    - Design for upgrades.
    - Design for second life with different function.
    - Create timeless look or fashion.
7. Design for optimized end-of-life.
    - Integrate methods for product collection.
    - Provide for ease of disassembly.
    - Provide for recycling, downcycling or closed-loop recycling.
    - Design reuse, or "next life of product".
    - Provide for reuse of components.
    - Provide ability to biodegrade.
    - Provide for safe disposal (34-39).

The strategy serves as a categorized checklist for designers to review as they develop products. Okala provides examples including a Dyson vacuum cleaner and a solar robotic lawn mower (37), but does not always provide more descriptive definitions for all of the strategies within the strategy wheel. It does provide more information on design for disassembly, lifecycle assessment, and extending product lifetime.

Industrial designers are often confronted with competing criteria that require the designer to find a harmonious balance. Sustainable design is no exception. Addressing and improving one aspect of a product's environmental impact may negatively affect another aspect. For example, specifying a low-impact biodegradable material may adversely affect the product's durability and shorten its usable life. The Okala guide provides the reader with some examples of typical tradeoffs. The important lesson is that designer's cannot address each of the strategies independently and must evaluate the effects of implementing certain design directions.

Life Cycle Assessment

Both *Design + Environment* and the *Okala Course Guide* discuss the value of performing Life Cycle Assessment (LCA). Performing an LCA is not a strategy itself, but performing and evaluating an LCA is one method for determining opportunities. There are a variety of LCAs used today, though environmental scientists disagree about the best method.

Life Cycle Assessment is a cradle-to-grave approach for assessing industrial systems. Cradle-to-grave begins with the gathering of raw materials from the earth and ends at the point when all materials are returned to the earth. LCA evaluates all stages of a product's life from the perspective that they are interdependent, meaning that one operation leads to the next. LCA enables the estimation of the cumulative environmental impacts resulting from all stages in the product life cycle, often including impacts not considered in more traditional analyses (e.g., raw material extraction, material transportation, ultimate product disposal, etc.). By including the impacts throughout the product life cycle, LCA provides a comprehensive view of the environmental aspects of the product or process and a more accurate picture of the true environmental trade-offs in product and process selection (Scientific Applications International Corporation 9).

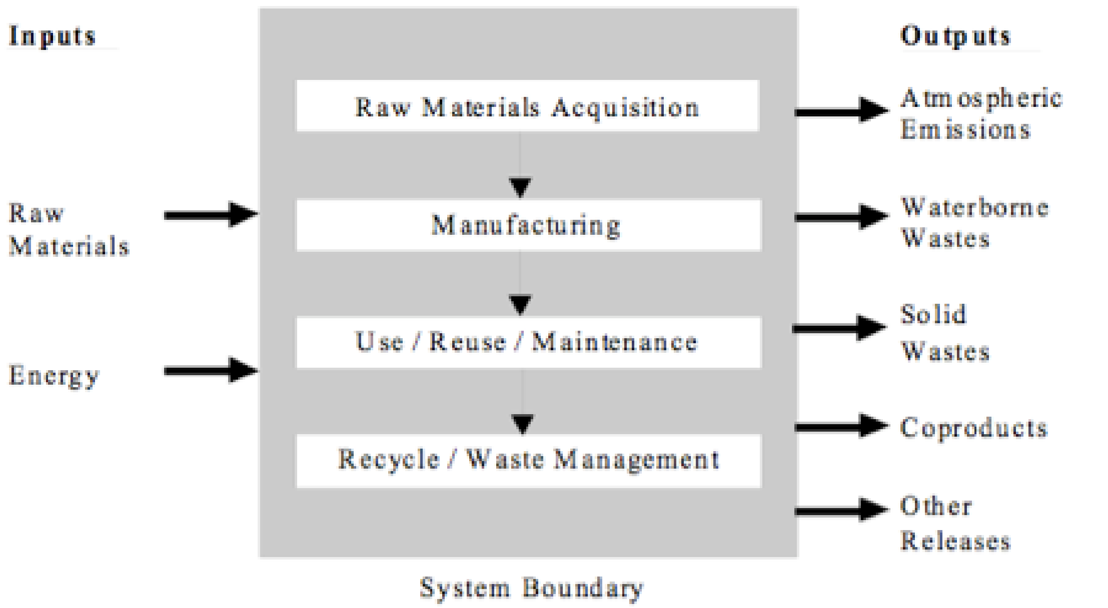

Exhibit 1-1. Life Cycle Stages (Source: EPA,1993)

Figure 2: Product life cycle stages

A full scale LCA uses original inventory data. If the assessment is intended to be made public, LCA software and a peer review by qualified experts is required. A single figure LCA is less complicated and relies on single figure scores based on previous assessment calculations. Okala uses the TRACI (Tool for Reduction and Assessment of

Chemical and other Environmental Impacts) LCA, which is a single figure LCA (IDSA "Okala" 45). The impact factors chart from the Okala Course Guide can be found in the appendix.

The Role of the Industrial Designer

In the product development process, the profession of industrial design lies at a strategic crossroads between management, marketing, engineering, and manufacturing. Management and marketing are typically responsible for defining much of the criteria for a product. It is driven by what the consumer wants, while engineering and manufacturing are typically responsible for developing and determining technical possibilities and how things are produced. Industrial designers are responsible for creating a balance that embodies all relevant design criteria determined by the group with a focus on human interaction, including aesthetics and human factors. To create effectively balanced solutions, industrial designers must possess at least a general understanding of the related disciplines including technical processes and requirements for manufacture, marketing opportunities and economic constraints and distribution sales and servicing. There are rarely distinct lines the fully separate the tasks and responsibilities of these disciplines (IDSA "ID Defined").

In the introduction to *Design + Environment*, Lewis and Gertsakis discuss the role of product designers as product developers, a multidisciplinary group including the industrial designer, engineer, model-maker, marketing manager, psychologist, technical writer, toolmaker and plastics specialist. They state, "In many ways it is more accurate to talk about eco-product developers rather than ecodesigners," (15) emphasizing the point that it is a collaborative effort among the disciplines will yield the most sustainable results. They further emphasize that the designer has the opportunity to emerge as a critical player, but working alone the designer's environmental role is limited (15).

Unfortunately, many designers work in organizations or for clients that place little priority on environmental concerns outside of meeting regulatory standards. In a survey conducted by the IDSA ecodesign section and the Silicon Valley Toxics Coalition in May of 2003, designers were asked about their level of influence over environmentally consequential attributes. The results show that the greatest influence lies in the industrial designer's ability to affect form, color and function, while the designers have significantly less influence over attributes such as flame retardants in plastics, plastic additives, toxins in electronic components and circuit board solder type. Other attributes scoring high on the survey include finish type, ease of disassembly and plastic type (IDSA "Electronic" 4).

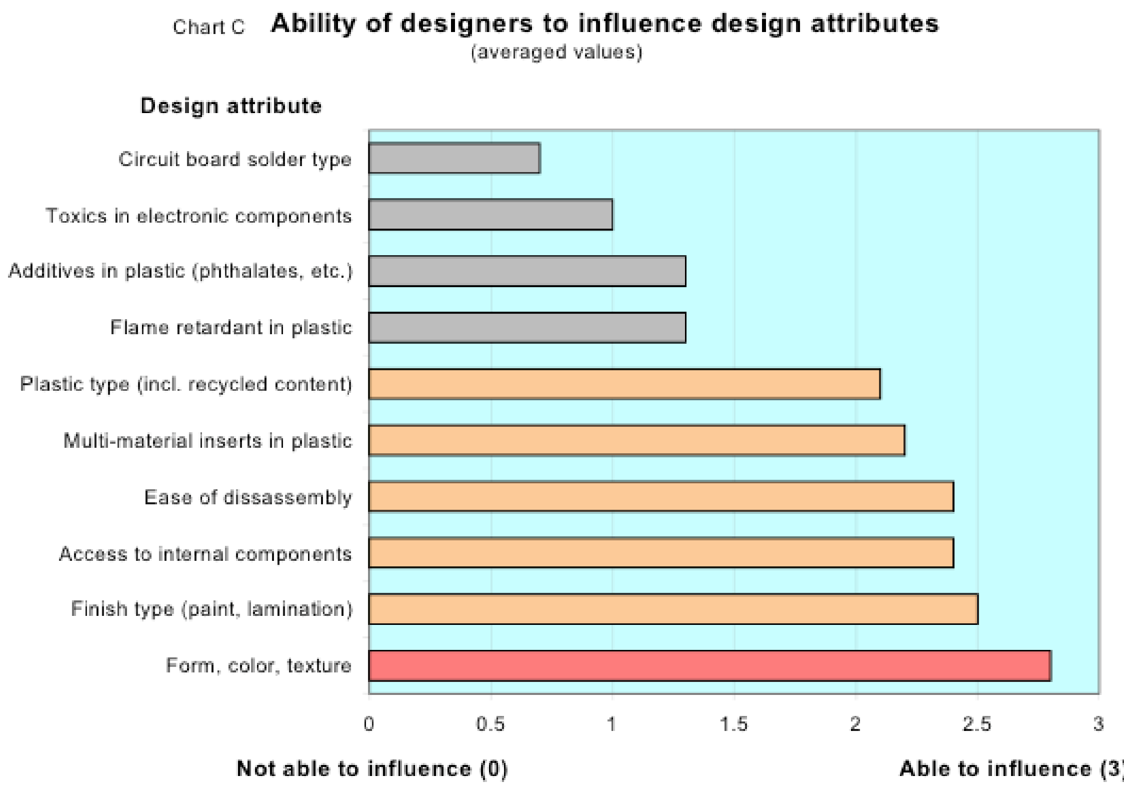

Figure 3: Ability of designers to influence design attributes

When designers were asked about the importance of environmental and human health impacts of products, the responses reflected a working environment where the designers consider the impacts very important while the designers' clients and managers consider the impacts significantly less important. Although this is encouraging, the results of another question place environmental impact last on the list of product quality priorities. Other product qualities include quality/performance, appearance and brand presence (IDSA "Electronic" 4-5).

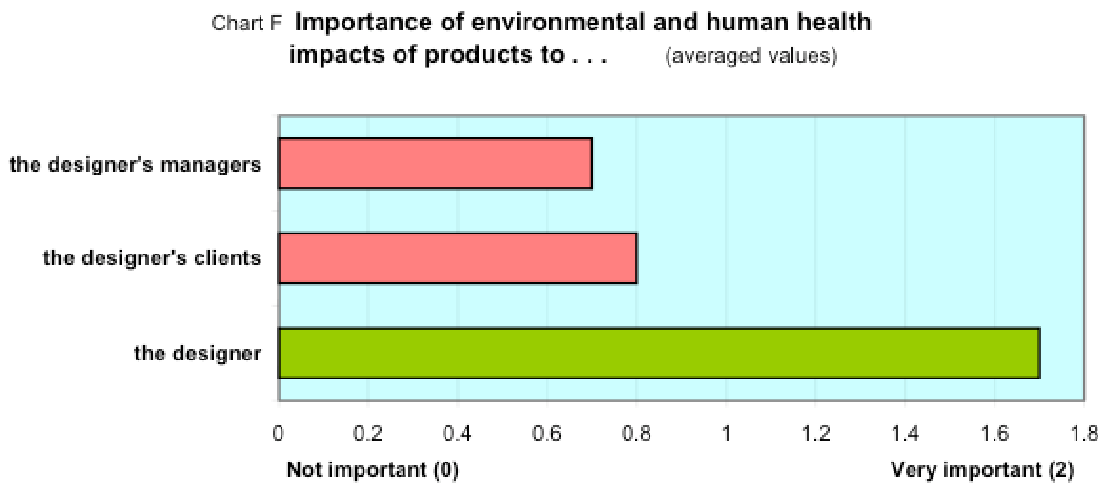

Figure 4: Importance of environmental and human health impacts of products to. . .

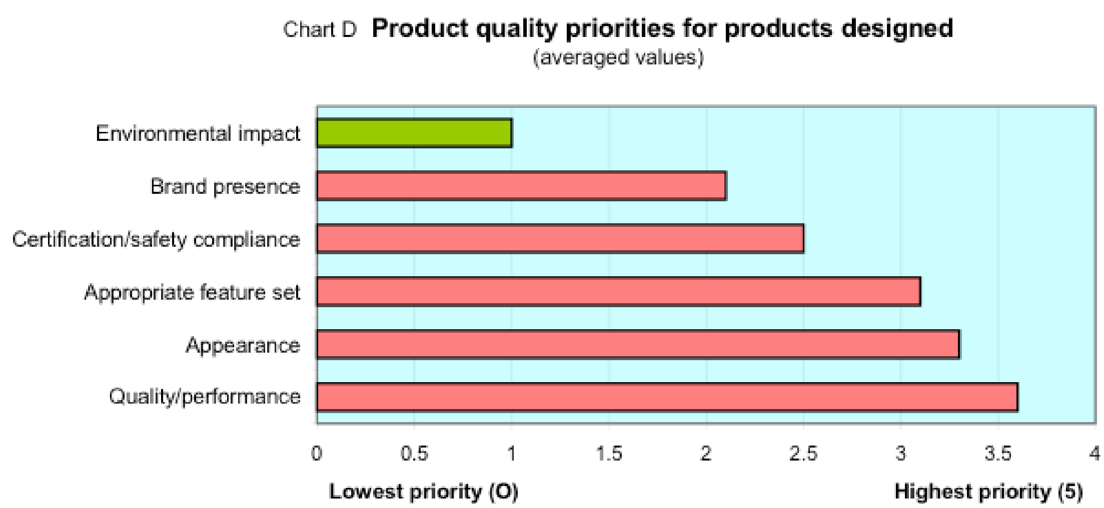

Figure 5: Product quality priorities for products designed

One conclusion that can be drawn from this survey is that designers are interested in pursuing environmentally sustainable solutions. However, the lack of priority placed on the environment by the designer's clients and managers is ultimately reflected in the priority of designers as they pursue their given tasks developing products. Therefore, many designers work within organizations or for clients that place little priority on environmental concerns outside of meeting regulatory standards, leaving these designers stranded and with little time and budgetary support to pursue progressive environmental initiatives.

Another survey conducted in 2004 by the IDSA sought to explore the gap between the designers' desire and ability to pursue environmental initiatives. The survey results show that designers need access to a variety of information that could help lead to effective decisions. This information includes international environmental regulations, environmental impact comparisons of materials and processes, design guidelines for disassembly and recycling, examples and suppliers of green materials, and examples of successfully ecodesigned products, preferably with economic considerations. (IDSA "EcoDesign" 5)

Without the education, experience, and budget to pursue sustainable solutions, designers must rely on self-education and the availability of easy to adapt sustainable tools to pursue environmentally friendly product design.

Summary

As discussed earlier, there are increasing pressures and incentive for government and business leaders to pursue environmental initiatives. It will take time for these initiatives to filter from the top-down into all product development practices. In the mean time, designers with conviction have an opportunity to address many environmental aspects of product development from the bottom-up. It is clear that there are no proven environmental methods that will work across all industries, business and product development practices.

The environmental movement and the pursuit of cleaner products are not new, but it is still in its adolescence and proving to be very challenging. If these challenges are addressed both from the top-down as well as the bottom-up, truly sustainable design can be achieved in a shorter timeframe.

Assumptions

The research literature is primarily based on studies done internally at companies and by firms. Therefore, the positive results are assumed to be true. For example, Interface claims that they saved over $60 million in the first few years of adopting a no-waste policy within their company. There are also assumptions based on recyclability vs. downcycling. Downcycling is viewed by some as a negative while others see it as a positive step in the right direction. This study will assume that downcycling is less desirable than 100% pure recycling. Environmental progress and digress are difficult to prove. For example, many view global warming as a natural cycle that the earth goes through rather than a side effect of human activity. There will always be debate as to whether future technology can overcome current adverse effects on the environment. This study will assume that man is contributing to global warming.

Scope and Limits

The study will focus on the individual industrial designer (junior and senior designers) and his/her ability to contribute to the environmental impact of the products he/she designs. The research will benchmark institutional and governmental trends, but be limited to individuals. The methodology developed during the study will mostly rely on results that have already been proven effective. The assessment portion of the methodology will be new and limited to a degree by the designer's ability to apply a general knowledge of material and process, perceived customer value, production cost, company politics, etc. The study will also rely upon the designer's personal ethical sense of responsibility as it relates to the environment. The study's scope will remain within the boundaries of product design. As with most design programs, the designer will propose environmentally friendly solutions, but ultimately it will be in the hands of upper management as to whether those suggestions are adopted. The designer's ability to change company policy or government regulation will be explored but only as suggestions. Although cost will be a consideration throughout the study, it will not be the focus. It is possible to compare change in cost to change in real and perceived value, however that study would require additional time that does not fit into the timeframe of this study.

Definition of Terms

Industrial Design: an applied art whereby the aesthetics and usability of products may be improved. Design aspects specified by the industrial designer may include the overall shape of the object, the location of details with respect to one another, colors, texture, sounds, and aspects concerning the use of the product ergonomics. Additionally the industrial designer may specify aspects concerning the production process, choice of materials and the way the product is presented to the consumer at the point of sale. The use of industrial designers in a product development process may lead to added values by improved usability, lowered production costs and more appealing products.

Sustainable Design: the art of designing physical objects to comply with the principles of economic, social, and ecological sustainability. It ranges from the microcosm of designing small objects for everyday use, through to the macrocosm of designing buildings, cities, and the earth's physical surface.

Recycling: the collection and reuse of materials that would otherwise be considered waste to produce new products. Motivations for recycling include environmental concerns, as recycling reduces the use of energy and raw materials and the need to dispose of waste, and for cost reasons, in situations where production from recycled material is less expensive than from new material. While an extensive variety of waste is recyclable, materials commonly recycled on an industrial scale include glass, paper, aluminum, asphalt, and steel. Recycled materials can be derived from pre-consumer waste (materials used in manufacturing), or post-consumer waste (materials discarded by the consumer).

Downcycling: the recycling of a material into a material of lesser quality. The obvious example is the recycling of plastics, which turns them into lower grade plastics.

Cradle To Grave: the philosophy that products are dumped into landfills at the end of their useful lives.

Cradle To Cradle: proposed product cycles whose materials are perpetually circulated in closed loops. Maintaining materials in closed loops maximizes material value without damaging ecosystems.

Energy Star: a government aided program helping businesses and individuals protect the environment through superior energy efficiency

LEEDS (Leadership in Energy and Environmental Design): Green Building Rating System is a voluntary, consensus-based national standard for developing high-performance, sustainable buildings

ISO Standards (International Organization for Standardization): ISO standards specify the requirements for state-of-the-art products, services, processes, materials and systems, and for good conformity assessment, managerial and organizational practice.

CHAPTER TWO

DEVELOPING THE SUSTAINABLE DESIGN METHODOLOGY

Developing the Sustainable Design Methodology

The following strategies are focused on the individual industrial designer within an organization lacking a serious commitment to environmental stewardship. There are many experts and professionals that play pivotal roles within an organization needed to create a sustainable product line. The strategies discussed in chapter one, whether they come from progressive companies or from more comprehensive design guides, include specific strategies that the individual designer has no control or influence over. In developing a methodology specifically for the individual designer, including all strategies will only add complexity to the methodology.

The goal is to simplify the methodology so that designers can pursue sustainable solutions in an efficient manner, complimenting the organization's design process rather than stalling it. The following strategies fall within the scope of influence of the individual industrial designer. Depending on the project, client or organization, the designer may have direct influence, indirect influence, or no influence over the following strategies.

There are two unique aspects to the new methodology. One is a revised assessment stage which addresses the designers influence over sustainable strategies. This stage is intended to further remove unneeded complexity and enable the designer to focus on the issues and strategies he/she does have influence over. The second unique aspect is the plug and play nature of the methodology. In an attempt not to overwhelm the designer with trying to address all of the strategies at once, different strategies are addressed at different stages in the design process with prioritized focus. This essentially provides the designer with a roadmap rather than just a list of strategies.

1. Opportunity Assessment

It is generally agreed that introducing environmental aspects as early as possible in the product design and development process increases the opportunity for designers and developers to consider environmental impacts and balance them with other development criteria.

For this reason, it is best to integrate the Sustainable Design Methodology at the beginning of each project. Initially, environmental impact should be addressed equally with other project criteria. By assessing the opportunities for improvement early on, additional opportunities may be present that may have been lost if address later in the process. An innovative new approach to how a company provides a value or service may shift the balance or prioritized criteria in favor of environmental solutions.

1.1 Environmental Opportunities Assessment

An individual industrial designer will likely not have the resources or access to needed information to perform a LCA on his/her own. By evaluating the pertinent information supplied by an LCA, a designer can still uncover opportunities to make a positive difference.

The tool below has been generated by streamlining the Okala LCA. Its intention is to adequately address the opportunities for the individual industrial designer. Rather than evaluating every component on the bill of materials or every sustainable design strategy, it is only necessary to address those that are within the sphere of influence of the designer.

In an oversimplified example, a designer is charged with redesigning a clock-face for a clock manufacturer. For reasons beyond the designer control, the clock must use the same clock mechanisms the company has been manufacturing for the past 25 years. In this case, it is not necessary to evaluate the clock mechanism as a potential opportunity. The designer should only focus on the components in the clock face itself, the hands, and any other part that the designer does have influence or control over such as evaluating supply chains and production efficiencies. The chart is divided into the main sustainable strategy categories of the methodology. The first thing the designer is able to do is review the strategy categories and determine whether they have direct, indirect or no influence over the strategy category on the current project.

Environmental Opportunity Assessment

Yes	May	No	Strategy Category	Possible Strategies	Component or Assembly	Notes	Advantages/Disadvantages
			Innovation				
			Low-Impact Materials				
			Optimized Manufactuing				
			Low-Impact Use				
			Optimized Lifetime				
			Optimized End of Life				

Figure 6: Environmental Opportunity Assessment (EOA) chart

2. Innovation:

The innovation strategy category is the most vague, but it presents the greatest opportunity for significant improvement. By addressing the environmental impact of a product at the beginning stages of the process, the designer has the best opportunity to innovate. Innovative solutions can be generated when the entire scope of the product is evaluated. Once the designer determines where the opportunities lie, he/she can work towards environmental solutions that encompass all criteria.

The most generic definition of innovation is: “the act of creating something new.” As applied to business, the definition becomes more specific by stating that an innovation must be “substantially different and increases value, consumer value or producer value. The succession of many innovations is one factor that can contribute to the growth of the economy as a whole.” (“Innovation”)

In addition to economic growth a significant innovation can change the way single or multiple industries approach certain challenges. Nike, for example, is exploring ways of tanning leather without the use of questionable toxins. By avoiding these toxins, the leather can maintain its role as a biological nutrient (McDonough, Braungart 181). It can be safely composted after use. There are many other industries that use leather including cars, furniture, and clothing. Nike’s success has the ability to impact all of these industries.

2.1 Innovation Strategy Questions:

By no means do the following questions represent the only ways to apply innovation to the sustainability of a project. By answering the questions, however, a designer may formulate new and innovative solutions.

- What is the ultimate value of the product or service and how is it currently being delivered? Are there other ways to deliver the good or service that reduce the environmental impact or benefits the environment?
- How are other companies providing the same or similar service?
- Is there a service or similar service provided in the natural world? What can we learn from examining those natural processes?
- Are there technological developments on the horizon that can be planned for?

The designer can begin to answer these questions by taking a look across the Sustainable Design Matrix and address all of the categories at once. Other solutions can be derived by benchmarking competitive solutions. Addressing innovative solutions before or during initial concept generation is likely the last opportunity to address the criteria as a whole and will likely lead to the most broad and sweeping alternative visions than at any later point in the process. As concepts begin to take shape addressing the non-environmental criteria, the window of opportunity to innovate in relation to the environment begins to narrow.

3. Low-Impact Materials:

Designers have traditionally selected materials based on their physical, chemical and aesthetic properties. Two additional criteria have been cost and availability.

Environmental parameters, such as resource depletion, are now proving more important (Fuad-Luke 282). When selecting materials based on environmental characteristics, it is important to consider them is relation to the life cycle of the product, examining the ease disassembly and recycling, for example. As discussed in the Assessment phase, it is also important to evaluate the process or processes used in the production of the product. This is more specifically addressed in the optimized manufacturing strategy category.

3.1 Minimize Material Use

Almost universally, material usage should be minimized without compromising the function, quality or aesthetics of the part. New and environmentally improved materials and processes are being developed at an increasingly rapid pace and should be used whenever possible. These could include materials with recycled content, materials made without any toxic or hazardous substances, materials derived from renewable sources, materials that are commonly recycled, materials whose processes are not energy intensive (Lewis, Gertsakis 149). Common ways to minimize material uses are as follows:

- Combine the functionality of multiple parts
- Sourcing a material that requires less material to accomplish the same function.
- Eliminating features / materials that are unnecessary to the core value being provided.

Material Selection

One of the most consistent opportunities as well as most difficult challenges for an industrial designer is to uncover alternative materials. Since most designers lack the necessary material science or engineering expertise, the designer must usually rely upon material experts, published sources and intuition to make material selection decisions.

It is important for the designer to be aware of new material developments. Material suppliers are usually willing to answer questions about the appropriateness of a material for specific applications. In a survey conducted by the IDSA in 2004, ranking numbers 2 and 3 respectively behind International Environmental Regulation, information comparing the environmental impacts of processes and materials is viewed as information necessary for working industrial designers to make sound ecodesign decisions (IDSA "Ecodesign" 9).

Material Checklist

Component/Current Material	Material	Impact Factor	Advantages	Disadvantages

Figure 7: Material checklist

3.2 Choose Ecomaterials

Ecomaterials are materials that are easily reintroduced to closed-loop cycles. Most have been developed with the environmental impact as a high priority and are being developed at an increasing rate. They have minimal impact on the environment while offering maximum performance for the required task (Fuad-Luke 282).

By taking the cradle to cradle approach as outlined by McDonough and Braungart, the only way to avoid a cradle to grave scenario, materials must be selected that are either biological or technical nutrients.

Products can be composed either of materials that biodegrade and become food for biological cycles, or of technical materials that stay in closed-loop technical cycles, in which they continually circulate as valuable nutrients for industry. In order for these two metabolisms to remain healthy, valuable, and successful, great care must be taken to avoid contamination one with the other. Things that go into the organic metabolism must not contain mutagens, carcinogens, persistent toxins, or other substances that accumulate in natural systems to damaging effect. By the same token, biological nutrients are not designed to be fed into the technical metabolism, where they would not only be lost to the biosphere but would weaken the quality of technical materials or make their retrieval and reuse more complicated (McDonough, Braungart 104-105).

A biological nutrient is a material taken from the biosphere that is designed to be returned to the biological cycle, consumed by microorganisms and other animals. Biosphere materials include compost-able biopolymers and biocomposites. On the other hand, a technical nutrient is a synthetic material that is designed to be returned to technical cycles. Many of them are derived from fossil fuels and require much more energy to be processed (McDonough, Braungart 105; Fuad-Luke 282).

3.3 Choose Materials with Low Embodied Energies

Materials represent or embody the energy required to produce them. Minimizing embodied energy is desired. Materials that require little processing and are extracted directly from nature tend to be low-embodied-energy materials. On the other hand, man-made materials often possess medium to high embodied energy. For example, aluminum takes more than a hundred times the energy to produce than the same amount of timber (Fuad-Luke 282).

3.4 Choose Materials with Recycled Content

Since many ecomaterials are new and unproven, a designer may have to use traditional materials. If possible, designers are encouraged to use as much recycled content to meet the needs of the product. The physical properties and tolerances of a material are often lessened when recycled, so it is sometimes necessary to use a mix of virgin and recycled material to meet certain requirements. By sourcing recycled content, a designer can lessen the impact of the material because a combination of recycled and virgin material will have less embodied energy than a purely virgin material.

3.5 Avoid Hazardous Materials

Hazardous materials should be avoided whenever possible. If it is not possible to completely avoid hazardous materials, take steps to minimize their use. Hazardous materials are those that are toxic, flammable, explosive, corrosive, ozone-depleting or contribute to global warming (Lewis, Gertsakis 76-79).

Toxicity is a complex subject, but like many other subjects, it is desirable for a designer to have general understanding of toxic materials. Toxicity refers to the ability of a substance or material to damage the health of an organism. The majority of materials can be toxic to living organisms if overexposed. In Europe, ROHS has taken steps to eliminate lead from PCBs. Until recently, the focus of toxicity has been on its effect on human beings, but environmental scientists are studying the ecotoxicity of materials, their effect on the environment, including fish, plankton, algae, aquatic insects, terrestrial plants and trees (IDSA "Okala" 17).

There are a number of relatively inexpensive or free resources where a designer can turn for information. For example, *EcoDesign: The Sourcebook* by Alastair Fuad-Luke, contains almost twenty pages of materials and finishes including composite boards, recycled polymers, textiles and paints (Fuad-Luke 284). This resource also provides readers with a table for evaluating the embodied energy values for common materials (283).

The *Okala Course Guide* includes a great deal of information about the environmental impact of materials as well as a chart with commonly used material impact factors. By evaluating potential material solutions in this chart, a designer can get a general feel for the positives and negatives of specific materials and processes. The chart is limited to common materials and processes and therefore may not prove to be as useful when evaluating new or less common materials, but assumptions can be drawn using comparative materials and processes within the chart (43-56).

Design + Environment includes an entire section dedicated to the advantages and disadvantages of commonly used material categories. It also includes an appendix listing hazardous materials and their impact, as well as industries and products that commonly use them (61-76).

4. Optimized Manufacturing

The inputs and wastes generated during the manufacturing process are rarely controlled by the industrial designer. However, there are a few strategies designers can attempt to address when it comes to optimizing the manufacturing process.

4.1 Minimize Manufacturing Waste

When a designer is designing parts that are fabricated from a sheet material, he/she should evaluate the amount of waste generated by the part geometry. For example, designing parts that will be CNC cut or laser cut from a sheet material, the designer should evaluate the nest-ability of parts. When designing parts for a thermoforming process, the orientation of the part can be adjusted to reduce waste.

4.2 Optimize part assembly

Designers should always review the product's assembly process. By creating a product that assemble easily or with less parts can reduce the energy required during assembly. Products that assemble easily will likely be easy to disassemble.

4.3 Choose a Cleaner Production Process

This is an example of a strategy that usually requires collaboration with production and purchasing staff and may be beyond the scope of influence of the individual designer. It is also likely that the designer may not have access to the necessary information to make informed decision. Again, the designer can begin to address this by referencing the Okala Impact Factors.

5. Low-Impact Use

During the development process, the designer is not only concerned with the environmental impact of materials and the processes used to manufacture the product. He/she must also be aware and design for the nominal use of the product. If the product consumes energy, water or additional materials during its use, it is important to address the efficiency of any additional inputs during the nominal use of the product.

This methodology focuses on three steps towards reducing the impact of a product during use. These three steps were adopted from the original five appearing in the Okala Strategy Wheel.

5.1 Reduce Energy Inefficiencies

Although it is not always possible, adopting a component such as a motor or fan that has been certified to meet Energy Star standards may be one way for a designer to improve the efficiency of energy use. In 2006, Americans using Energy Star products saved more than $14 billion on their utility bills and help prevent 37 million metric tons of greenhouse gas emissions. This value is the equivalent to the annual emissions from 25 million vehicles. Energy star qualified products include battery charging systems, compact florescent light bulbs, and ventilation fans (Energy Star “Energy”).

Conventional battery chargers can use as much as 5 to 20 times more energy than is actually stored in the battery and systems are available that use 35% less energy on average (Energy Star “Battery”). Nokia, along with a recent agreement between all mobile phone manufacturers to focus on energy usage and environmental impact, has been developing a system that takes it one step further. Nokia will add alerts to the phone that let the user know that the battery is full and encourages users to unplug at that time (Gizmag).

5.2 Reduce water use inefficiencies

In *Green to Gold,* Esty and Winston ranks water as the third most important environmental issue behind climate change and energy (33). If possible, a designer working on a product that consumes water should evaluate the manner in which it uses water and explore opportunities to reduce inefficiencies.

One industry-wide example of water conservation is the washing machine industry. A recent trend in washing machine design incorporates efficient front-loading machines that use only 18-25 gallons of water per load compared to and average of 40 gallons per load in traditional machines (Nobile-Goodman). LG Electronics has developed an efficient washing machine that incorporates steam into the washing cycle. One feature of the new washer is a 20-minute steam cycle that uses steam to reduce wrinkles and refresh clothes without the use of water or detergent. A second option allows the user to combine steam with hot or warm water in a washing cycle (LG Electronics). Another example presented in the *Okala Course Guide* is a combination sink / toilet that re-uses the water from the sink in the toilet (37).

5.3 Reduce other consumable use inefficiencies

Many products rely on filters, ink cartridges, detergent and other consumables throughout their use. These consumables should be considered products in-and-of-themselves. Examine the consumable and explore opportunities to eliminate or minimize their environmental impact.

Pioneered by Dyson, vacuum cleaners are now being produced that no longer require bags for operation. Coffee makers have developed permanent filters that replace paper filters. Pay-at-the-pump printers utilize thermal printing, therefore eliminating the need for ink cartridges.

6. Optimized Product Lifetime

There are a number of strategies that can be applied to optimizing a product's usable lifetime. Typically, it is desired to extend the lifetime of a product as much as possible. Five steps can be taken to accomplish this: durability, designing for ease of service and repair, anticipating technological changes, creating modular assemblies, and standardizing on as many parts across the companies product line.

6.1 Durability

Durability can be a double-edged sword. By using durable materials and practices that resist breakage and environmental degradation, products will likely be less biodegradable. However, extending the life of a product can prevent users from replacing the product.

6.2 Ease of Service

Some components of products are inherently more likely to fail. Moving parts are subject to a greater failure rate than non-moving parts. As overall assemblies are designed, it is desirable to create an easy way for service technicians or even end users to access and replace parts more likely to fail.

6.3 Commonization of Parts

Designing products that share parts reduces inventory complexity and increases the ability for users and technicians to service and repair products. As discussed earlier, Xerox designs many of their products to share the same components, allowing Xerox multiple options for returned or broken equipment. Parts can be easily replaced, remanufactured into machines of the same type, manufactured into machines in the same product family or used in the development of future models (Xerox).

6.3 Anticipation of Technological Change

In the fast paced technological and business environment of the 21st century, new technologies are being developed at a rapid pace unprecedented in history. By understanding the technologies that are incorporated and related to the products being developed, designers can plan ahead and anticipate changes. In many cases, features can be designed that will allow products to work with current and future technological trends.

Sony recently introduced a new video game console that also plays Blue-Ray DVDs. By adding this emerging technology, purchasers of the Playstation 3 will not have to purchase a standalone Blue-Ray DVD player.

6.4 Modular Assemblies

Another way to possibly extend a product's usable lifetime is to create modular assemblies. When looking at a product as a whole, new technological developments do not always require replacing the entire product. Computers, for example, have had many components in common with previous versions: display, keyboard, and mouse. Technological advancements in the computer industry typically center around processing speed, storage space and memory. In many cases, computers can be upgraded to current speeds and storage capacity.

7. Optimized End-Of-Life

Most products have a limited lifetime. A lack of mandatory take-back legislation in the United States means that designers have little control over the disposal of products. However, the following strategies begin to address what can be done once a product has reached the end of its usable life.

7.1 Design for Disassembly

A key step a designer can take to optimize the end of a product's life with regard to the environment is to design the product for ease of disassembly. Automated disassembly is not yet fully possible; it is believed to be possible by 2020. This means that the majority of products need to be disassembled manually. Okala proposes a number of steps a designer can take to design for manual disassembly.

- Minimize the time required to separate products into parts.
- Design for ease of repair, cleaning and enable easy replacement of parts when worn out or obsolete.

- Design for easy removal of hazardous components (batteries, circuit boards) prior to recycling or shredding.
- Avoid fixing dissimilar materials together so that they cannot be separated (for instance, no molded-in or glued-on metal parts in plastic).
- Design sub-assemblies so they are easily separated into fragments with different waste treatments.
- Dried paint should not exceed 1% of the total weight of a plastic part.
- Label parts greater than 25 grams to identify their polymer type (for manual disassembly) (IDSA "Okala" 33).

7.2 Design for recycling

When using a material categorized as a technological nutrient, it is important for a designer to take steps to allow for an easy return to the closed loop cycle. There are a number of economic factors associated with recycling. The costs associated with recycling are collection, disassembly, and the recycling process. A designer should keep all of these in mind and work to minimize the cost. Positive economic factors include profit derived from avoiding waste disposal as well as the profit from selling recycled material (IDSA "Okala" 31).

Designing parts for quick disassembly is a key step to reduce the cost associated with recycling. Although it is possible to identify plastic types with infrared scanners, it is important for designers to label plastic type when possible. By allowing recyclers to separate plastics effectively, they can be processed purely and reused in new products, avoiding downcycling.

Two examples of downcycling are metal components in an automobile and aluminum alloys in the typical soda can. There is no current technology that separates the polymer and paint coatings from automotive metal before it is processed. Aluminum cans are typically made with two kinds of aluminum including an aluminum magnesium alloy as well as coatings and paint. When recycled, these two examples are typically melted together resulting in a downcycled, less useful product (McDonough, Braungart 57; IDSA "Okala" 31).

7.3 Design for biodegrading

This mostly relates to material selection detailed in "Low-Impact Materials". If the designer does not specify a technological nutrient, he/she can specify a biological nutrient, which can biodegrade and be returned to the earth as food. It is important to isolate biological nutrients so that they can be processed purely. It is also important to communicate to the user that the product or components can be composted when appropriate.

7.4 Integrate Methods for Product Collection

Many countries are beginning to legislate take-back programs. The decision to institute a take back program rarely rests with the designer. Designers can encourage take-back programs by presenting mangers and executives with incentive to do so. There are a number of incentives that can be presented including green marketing, consumer loyalty, and anticipation of new government regulation that may mimic those in Europe.

7.5 Design for Re-use

It is possible to design a second life into some products. In the 1950's, Heineken designed a bottle that incorporated an innovative rectangular form factor allowing the bottles to nest and be stacked. The bottle's intention was to be used as a building block or brick and also possessed good insulation properties (Boing Boing).

In 2005, computer manufacturer NEC created a buy-back program. NED repurchases, refurbishes and resells secondhand computers it manufactured in the first place. This program effectively extended the life of certain parts and components (Ms. N).

7.6 Provide for Safe Disposal

If a product contains toxic materials, such as batteries that are not safe for typical disposal in a landfill, it should be clearly labeled for decontamination and disposal. Toxic materials that could contaminate surface or ground water, such as inks, dyes, pigments, stabilizers, solders and adhesives should be avoided if possible (Lewis, Gertsakis 94).

Sustainable Roadmap

The goal is to create a sustainable design methodology that can be easily adapted to any internal design process. The design process used as an example in the following methodology includes: criteria definition, research and observation, concept generation, concept refinement, prototype and testing, and design for production. The sustainable design methodology attempts to provide a roadmap for designers.

The methodology is broken down into the seven main categories described earlier. A significant difference in this new methodology is that it takes the steps of a generic design process and provides the designer with which sustainable strategies should be focused on in each of the steps of the design process. (See figure 8) The methodology not only tells the designer when to focus on what, it also places priorities on some strategies within each step.

The Design Process

The logic and reasoning for placing specific sustainable strategies within specific steps of the design process are described below. By reviewing what typically takes place during each step of the design process, it is possible to evaluate which strategies are most appropriately applied to each step.

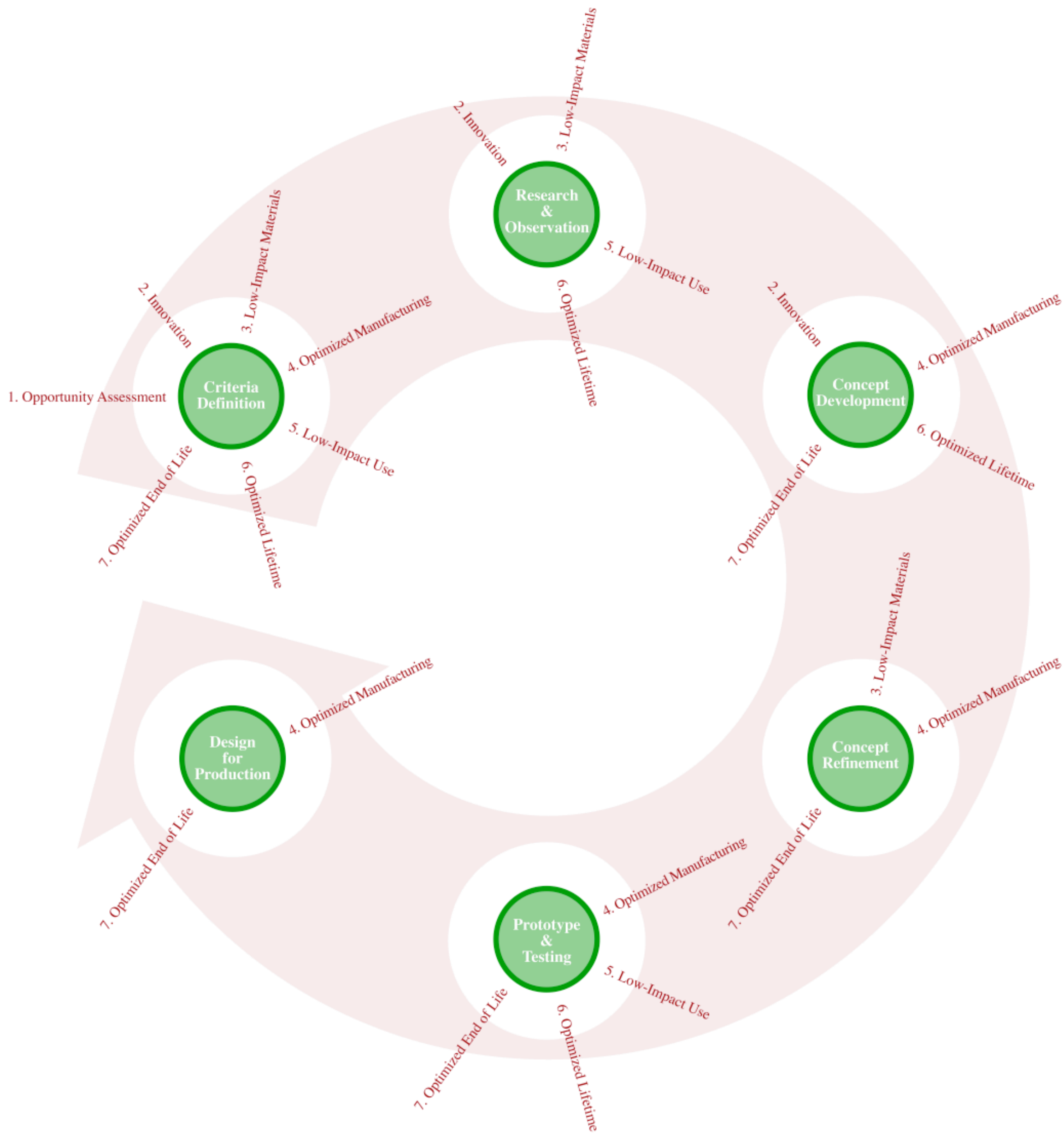

Figure 8: Sustainable Methodology Process

Criteria Definition

Criteria addressing the functionality, budget, target market, etc. of a project is typically established at the beginning of each project. Often, much of the criteria for the program as a whole is created prior to the involvement of industrial design. However, a design team will adapt the criteria to meet the scope and responsibility of the design team. As discussed earlier, it is important to address sustainable issues at the earliest possible opportunity. For that reason, a designer should utilize the environmental opportunity assessment tool. Since one of the aspects of the environmental opportunity assessment tool is to determine which of the sustainable strategies can be addressed on the project, the designer briefly reviews all of the strategies. This is also the best opportunity to ask innovative questions, which may dramatically alter the criteria.

- Major Focus
    - Assessment
    - Innovation
- Secondary Focus
    - Low-Impact Materials
    - Low-Impact Use
    - Optimized Lifetime
    - Optimized End of Life
- Tertiary Focus
    - Optimized Manufacturing

Research and Observation

Once the criteria have been established and sustainable strategies have been highlighted as potential opportunities or eliminated, the design process enters the research and observation phase. At this phase it is still appropriate to explore innovative solutions. It is also a good time to research low-impact materials, low-impact power and water solutions and look into technological trends that may extend product lifetime.

- Major Focus
  - Innovation
- Secondary Focus
  - Low-Impact Materials
  - Low-Impact Use
  - Optimized Lifetime

Concept Development

By the time initial concepts are generated, the designer has a full understanding of where sustainable opportunities lie and has had the opportunity to further explore those opportunities through research. It is not yet time to stop focusing on innovation. Traditionally, most innovation takes place during initial concept generation. Concepts generated during this phase can push the limits of the criteria and what is possible. While addressing core criteria, such as function, features, and styling, innovation strategies should remain the focus at this time. It is also a good time to review optimized manufacturing, optimized lifetime and optimized end of life strategies as a secondary focus.

- Main Focus
  - Innovation
- Secondary Focus
  - Optimized Manufacturing

        - Optimized Lifetime
        - Optimized End of Life

Concept Refinement

By the time initial concepts are narrowed down, much of the overall direction of the project is established. From this point on, it is time to put a heavier focus on specific strategies. This is typically the time for computerized 3D models of the product. It becomes increasingly important for a designer to make a decision on materials. It is also important to address assembly and disassembly issues. By the end of the concept refinement phase, the concept should be ready for prototyping.

- Main Focus
    - Low-Impact Materials
- Secondary Focus
    - Optimized Lifetime
    - Optimized End of Life
- Tertiary Focus
    - Optimized Manufacturing

Prototype and Testing

It is best to fabricate prototypes from the proposed production material; however, this is not always possible or within the prototyping budget. If not, designers should try to utilize a prototype material that will simulate the durability of the production material. This phase should be viewed as an evaluation phase of what has been accomplished to date. For example, the designer can evaluate the ease of which the components are assembled. It is often easier to generate ideas to improve how a product goes together and comes apart with physical samples. Usage efficiencies, such as energy and water, can be tested when a working prototype is fabricated.

- Main Focus
  - Low-Impact Use
  - Optimized End of Life
- Secondary Focus
  - Optimized Manufacturing
  - Optimized Lifetime

Design for production

The final phase of the development process is when the designer can make revisions based on what was learned through evaluating the prototype. The product is readied for manufacture. Obviously, the most appropriate sustainable strategy to focus on is optimizing the manufacture of the product. It is also the best time to ensure that any information pertaining to proper disposal or recycling needs to be molded into parts or otherwise communicated.

- Main Focus
  - Optimized Manufacturing
  - Optimized End of Life

Sustainable Strategies Matrix

Rather than graphically represent the appropriate time to address the strategy categories in the context of a circular design process as in Figure 8, a matrix format

(Figure 9) condenses the information and is easier understand. A color-coded system correlating the priority of focus is also applied to the matrix. The red dots represent the designer's main focus. The darker grey dots represent secondary focus, with the lighter grey representing tertiary focus.

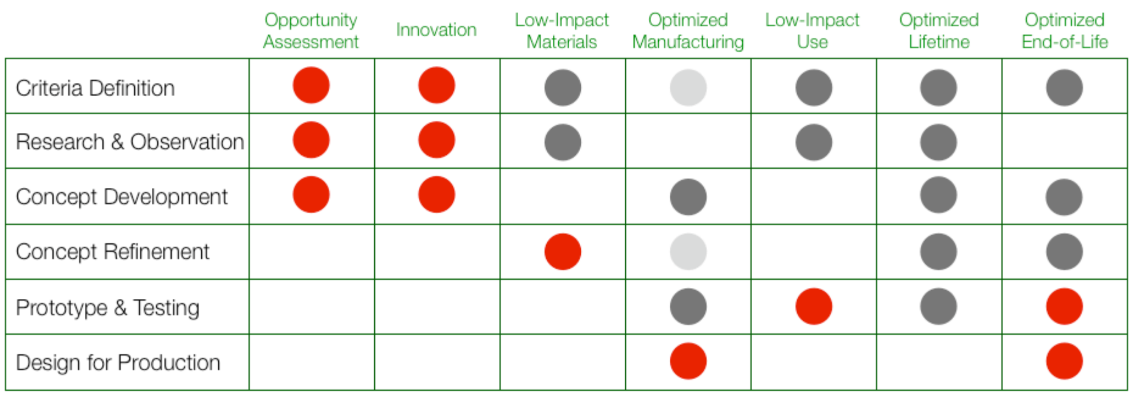

Figure 9: Sustainable Methodology Matrix

CHAPTER THREE

APPLYING THE METHODOLOGY

Applying the Methodology

The following project represents how the new sustainable design methodology could be applied to a product redesign. The original product was designed in early 2004 as an accessory product to the iPod Shuffle. The product served as a portable docking stereo. It included an auxiliary audio input, allowing users to utilize the stereo with any audio device capable of audio output through a 1/8” stereo jack. The original criteria focused on portability, a unique form factor, styling, and cost. The criteria did not include an environmental concerns extending beyond regulatory standards. A computer rendering of the original product is pictured in figure 10. A list of features and other important information pertaining to environmental impact is listed below:

- iPod Shuffle dock.
- Portable stereo.
- Auxiliary audio input.
- Inexpensive, stereo speaker drivers.
- Inexpensive, off-the-shelf amplifier and circuit board.
- Power source.
    - 4 AAA batteries.

- Non-rechargeable batteries.
- AC power adapter.

- Virgin ABS enclosure.
- Welded assembly (ultrasonic and heat staking).

Figure 10: First generation stereo design

The product never made it to production due to Apple Computer’s introduction of the iPod Nano in September of 2005. The client requested a redesign of the product that would dock the iPod Nano rather than the iPod shuffle. Much of the criteria and features remained the same, including the lack of environmental concerns. One addition was the incorporation of on-board volume control.

Figure 11: Second generation stereo design

As with the first generation concept, the revised concept was abandoned and never made it to production.

Redesign with Sustainable Design Methodology

This product redesign was chosen to test the methodology for a number of reasons. The product consisted of a number of sub-assemblies, including electronics, but is not overly complex. The product is an accessory product for the highly successful line of Apple iPods, which are revised and updated frequently. The accessory market for iPods has experienced tremendous growth since the introduction of the first iPod in 2001.

Criteria Definition

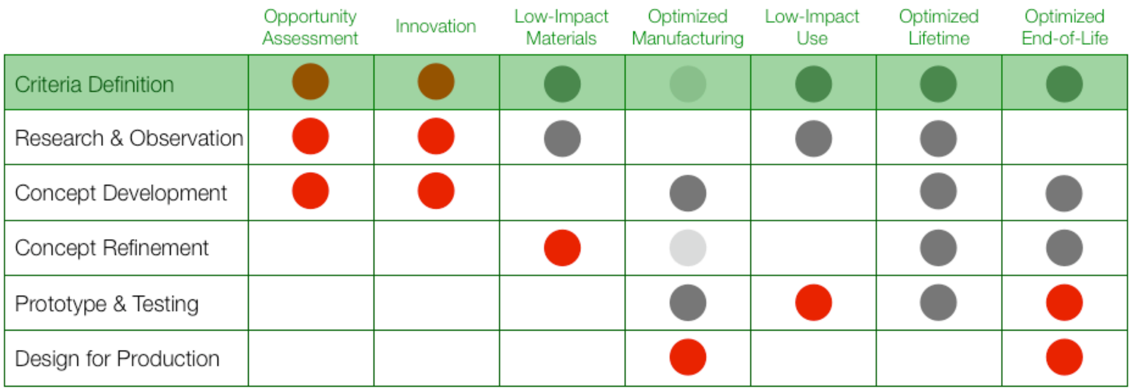

Figure 12: Sustainable methodology matrix – criteria definition

The sustainable design methodology matrix defines the strategy categories that should be addressed during the criteria definition phase of the project. It is highlighted in green in figure 12. It also tells the designer where he or she should focus their efforts on the assessment and innovation strategies, while still evaluating the remaining strategies with less focus. The designer should fill out the environmental opportunity assessment form. Since the chart includes assessing the designer's influence and opportunities for all of the remaining strategies, it is the only necessary task to complete during criteria definition. See figure 13 for the completed form. Note that the assessment column is filled with a red dot through the concept development phase. Strategies and notes should be added as the designer moves forward through the design process.

As the left side of the completed chart shows, the designer has influence over the following strategy categories: innovation, low-impact materials, low-impact use, optimized lifetime, and optimized end-of-life. The designer is unclear of his opportunities and influence over optimized manufacturing and low-impact use. By taking this step, the designer knows where to focus his energy while conducting research.

Environmental Opportunity Assessment

Yes	May	No	Strategy Category	Possible Strategies	Component or Assembly	Notes	Advantages/Disadvantages
X			Innovation	Anticipate Tech Change	Housing/Dock	Can the redesign work with multiple iPods?	Adv: Works w/ multiple prod.
X			Low-Impact Materials	Ecomaterial			
				Recycled Content			
	X		Optimized Manufactucing	Ease of Assembly?		What are the best assembly methods?	
	X		Low-Impact Use			Are there alternative ways to power unit?	
X			Optimized Lifetime	Modularity	Housing/Dock	Can the redesign work with multiple iPods?	
X			Optimized End of Life	Des. For Disassy		The product currently uses ultrasonic welding	Adv: separate parts Dis: Mechanical fasteners
				Design for Recycling		By creating a way to disassemble parts	Adv: close loop
				Provide for Disposal	PCB, Batteries	Acid in batteries, lead on circuit board	Adv: avoid water contam.

Figure 13: EOA – criteria definition

Further review of the chart points out more specific research needs. Although the designer listed two possible strategies in the low-impact materials section, more research is needed to determine the best material for the application. The chart also shows the need to look into alternative ways to power the device.

The designer has already uncovered a strategy to extend the life of the product by designing the product to accept multiple versions of the current iPod product line. This is listed in the innovation section, because the designer in also anticipating, based on past behavior by Apple, continued evolution of the iPod product line.

Research and Observation

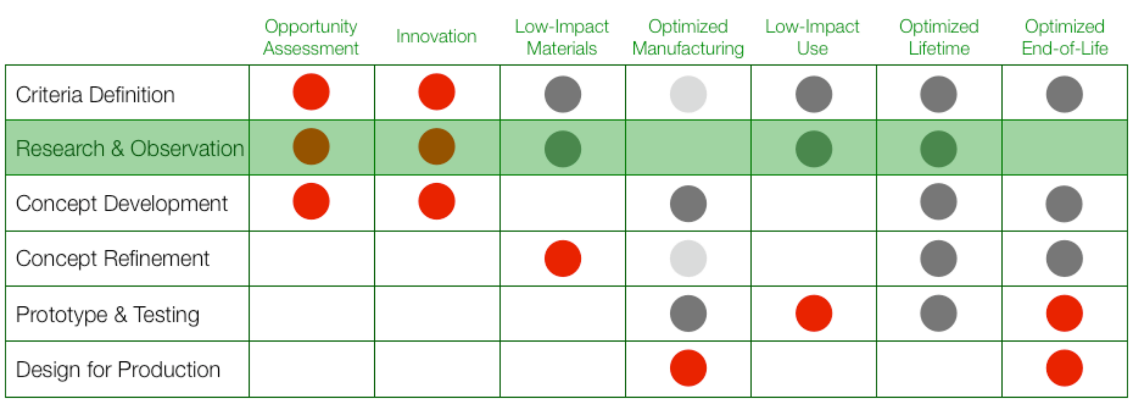

Figure 14: Sustainable methodology matrix – research and observation

Very little changes on the sustainability matrix when the designer reaches the research and observation phase. By reviewing the left side of the EOA chart, there is or there may be opportunities for improvement in every strategy category. The blank fields indicate that research may uncover those opportunities in more detail. Due to the high tolerance required for the product as well as the anticipated volume, it is likely that the enclosure will be injection molded. In researching new ecomaterials on the internet, two bioplastics show promise, a corn-based plastic by Natureworks and a wood-based plastic called Treeplast. Both materials can be molded in traditional machines and both are derived from renewable resources. The materials are added to the environmental opportunities checklist. A third material option is to continue using ABS, but with a percentage of recycled content. Research also uncovered a number of products, including some iPod accessories, that utilize solar and human power.

Environmental Opportunity Assessment

Yes	May	No	Strategy Category	Possible Strategies	Component or Assembly	Notes	Advantages/Disadvantages
X			Innovation	Anticipate Tech Change	Housing/Dock	Can the redesign work with multiple iPods?	Adv: Works w/ multiple prod.
X			Low-Impact Materials	Ecomaterial	Treeplast Natureworks PLA	good acoustic resonance mostly used in packaging	Adv: Both are renewable Dis: Heat and env. Resistance
				Recycled Content		what is the highest percentage of recycled content we can get away with?	
	X		Optimized Manufactuing	Ease of Assembly?		What are the best assembly methods?	
	X		Low-Impact Use	Solar		Are there alternative ways to power unit? Solar power is nixed by management!	
				Crank Powered		Too complex, nixed by management	
X			Optimized Lifetime	Modularity	Housing/Dock	Can the redesign work with multiple iPods? Microsoft Zoon introduced - compatibility?	
X			Optimized End of Life	Des. For Disassy		The product currently uses ultrasonic welding	Adv: separate parts Dis: Mechanical fasteners
				Design for Recycling		By creating a way to disassemble parts	Adv: close loop
				Provide for Disposal	PCB, Batteries	Acid in batteries, lead on circuit board	Adv: avoid water contam.

Figure 15: EOA – research and observation

Concept Development

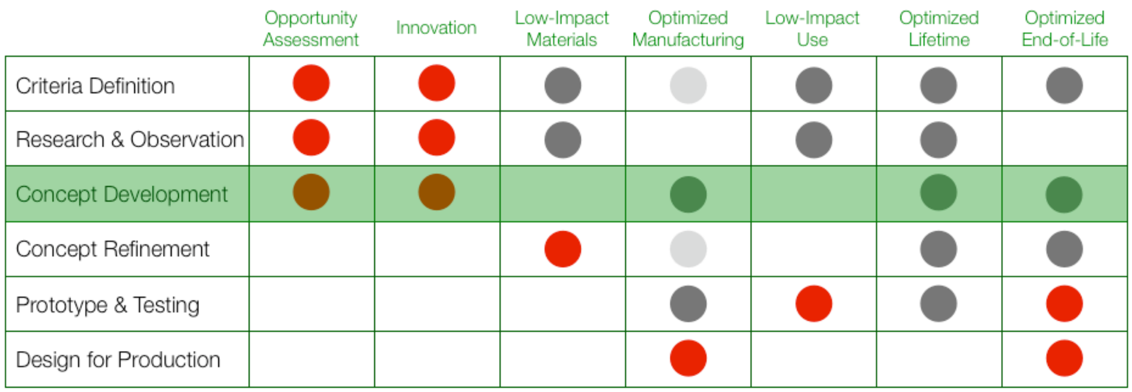

Figure 16: Sustainable methodology matrix – concept development

The initial round of sketch concepts include a modular docking concept, allowing the product to be used with multiple iPod models including the iPod nano and the 5G iPod that plays videos. All of the concepts are designed for disassembly so that components can be separated at the end of the products useful life.

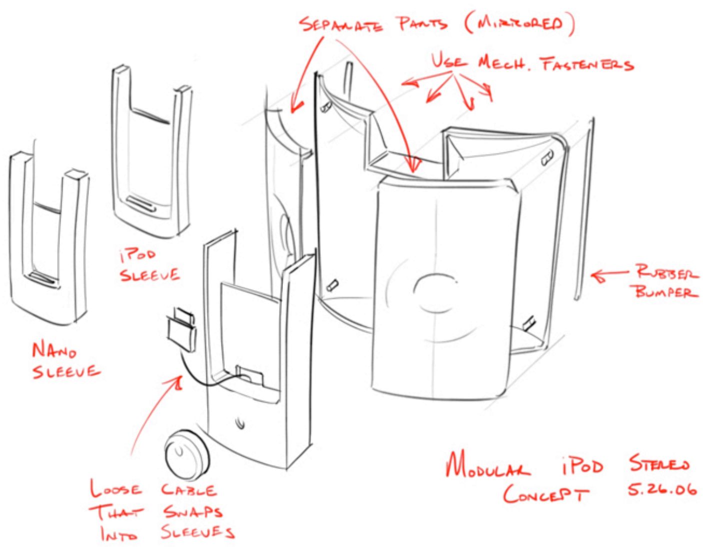

Figure 17: Stereo concept sketch

Additional concepts include those that are powered by solar power and by a hand crank. The decision is made to abandon the solar and human powered concepts due to technical complexity, aesthetics and cost. The sketch in figure 17 is selected as the go-forward direction.

Concept Refinement

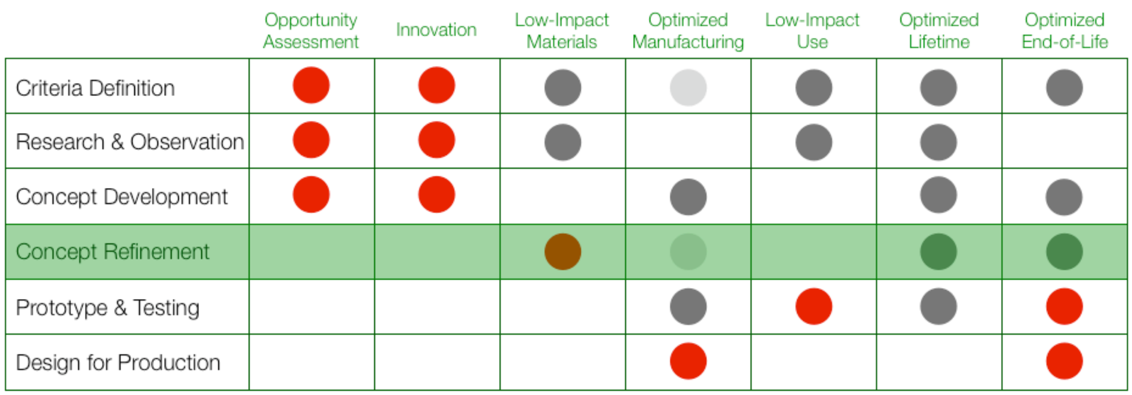

Figure 18: Sustainable methodology matrix – concept refinement

The sketch concept is further refined as a computerized 3D model and prepared for prototyping in the concept refinement stage. To effectively design the product, it is necessary to determine optimal wall thickness for the enclosure. The optimal wall thickness may vary depending on choice of material. By contacting the material suppliers, it is learned that Treeplast is not readily available for commercial products and that Natureworks PLA is commonly used in short term applications such as packaging.

Due to reliability and quality control, ABS with recycled content will be used for the enclosure. The CAD is developed with design for disassembly as a priority, utilizing mechanical fasteners and snap-fit battery connectors. Another priority is to determine the best way to create the modular dock to fit the larger 5G iPod as well as the iPod Nano.

Additionally, steps are taken to anticipate for future models, assuming that future models will continue the trend of decreasing in size. Figure 19 shows an exploded view of the refined concept.

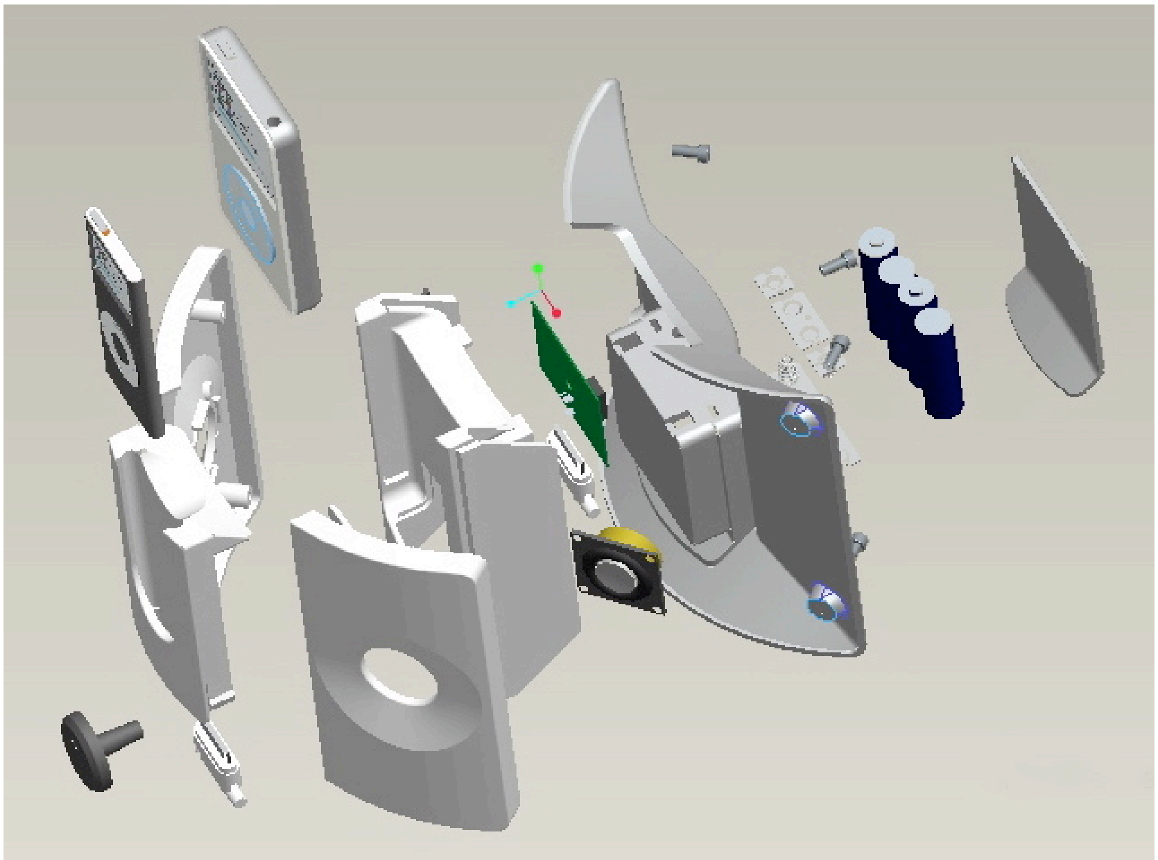

Figure 19: Exploded view of stereo concept

Prototype and Testing

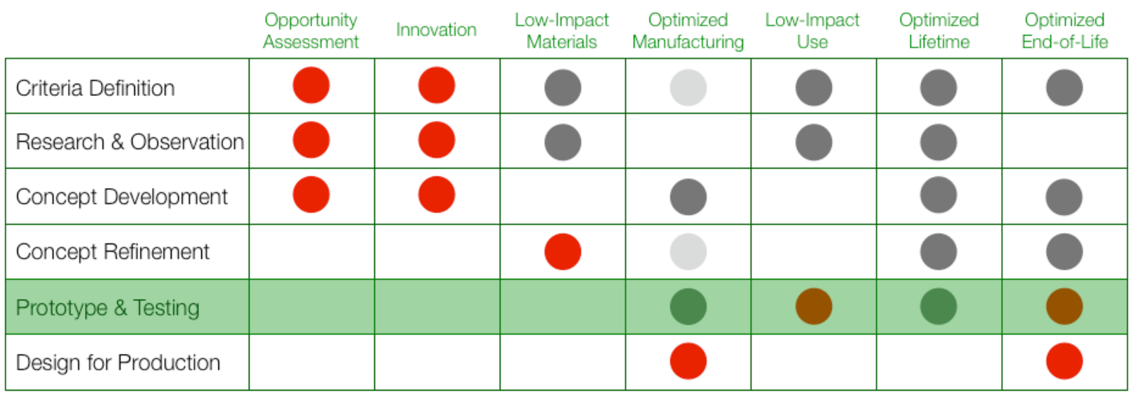

Figure 20: Sustainable methodology matrix – prototype and observation

Prototyping is a key step to any design process. Here, it provides a great opportunity to evaluate the progress of certain sustainable strategies pursued to this point—specifically the ease of assembly and disassembly. With a few exceptions the parts fit together well and require little effort to assemble and disassemble. The exceptions include the circuit board and the two iPod models. The circuit board lacks the needed clearance to allow the power module to adequately snake around the needed hole. The docking areas for the two iPod models are both too snug and will require additional clearance.

Five mechanical fasteners hold the enclosure together while also positioning the circuit board. Each speaker driver is held in place with four small screws. To disassemble the product, a total of only 13 fasteners need to be removed along with the snap-in battery contacts. Once that is complete, the recyclable ABS is completely isolated from other materials that would contaminate it. The batteries and circuit board are also able to be disposed of properly.

If the product needs to be opened and closed multiple times throughout its life, it would probably require mechanical threaded inserts to avoid stripping the plastic bosses. However, the only times this product will need to be taken apart is when serviced or disposed of at the end of its usable life. For that reason, the decision is made to stick with plastic bosses to avoid contaminating the plastic.

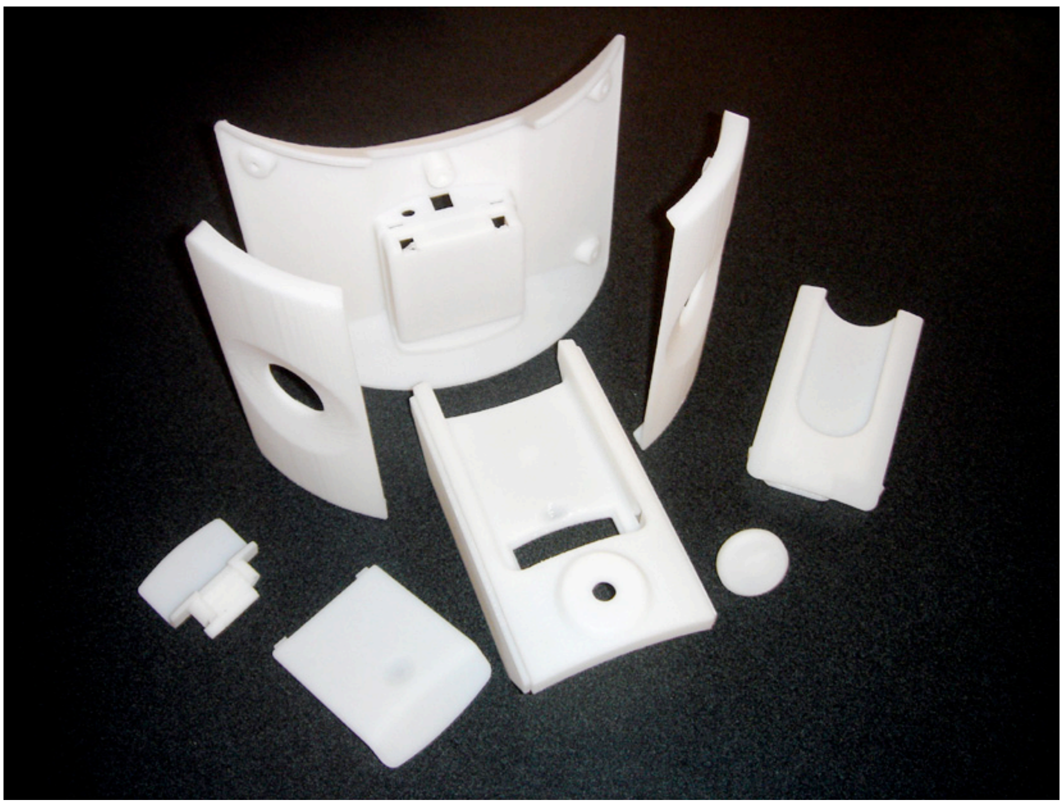

Figure 21: Rapid prototype of stereo concept

The other main focus category during prototype and testing is to address low-impact use. If the prototype includes the circuit board, the efficiency of power usage can be evaluated. This prototype is non functional and does not include the circuit board.

A new idea with sustainable impacts is conceived during this phase that does not entirely fit into the matrix. In evaluating what could be done to address the circuit board, and more specifically the power input module, it is determined that a different connector could be used. By incorporating a mini-USB connector as the power input component, it is possible to ship the product without a 12V power adapter. Since the product is designed to be used with an iPod, this product can take advantage of the power brick that is supplied with each iPod, thus reducing the overall impact of the product.

Design for Production

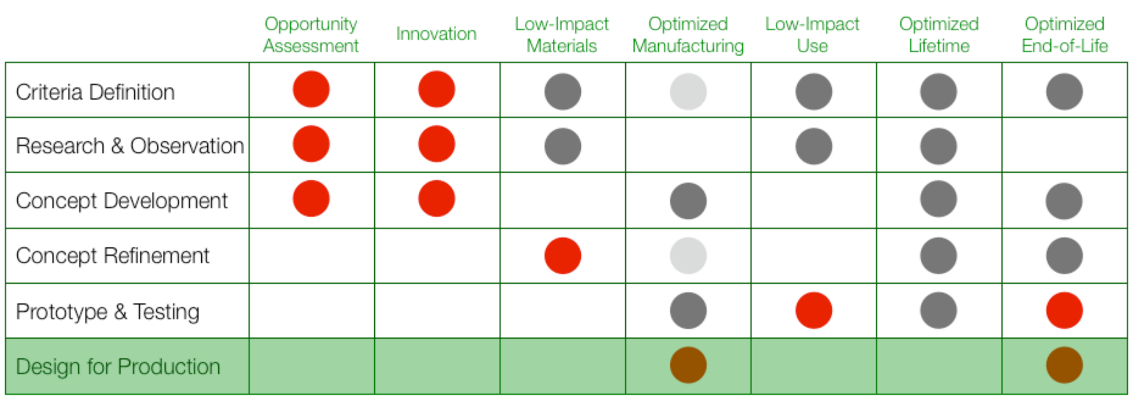

Figure 22: Sustainable methodology matrix – design for production

By the time the design process reaches design for production, most sustainable strategies have been explored and implemented. There are a few final tasks to ensure that the product can be disposed of properly at the end of life. The first is to make any changes uncovered during the evaluation of the prototype. The necessary changes are made to the parts allowing optimal fit of the iPods.

Second, a review of the optimized for manufacturing and optimized end of life strategy categories should address any applicable strategies taken. In this case, the circuit board fit issue is resolved. Also, any information that the consumer or reclaimer needs to know about proper disposal should be added to the parts. The ABS parts are embossed with the appropriate recycling code.

The Final Solution

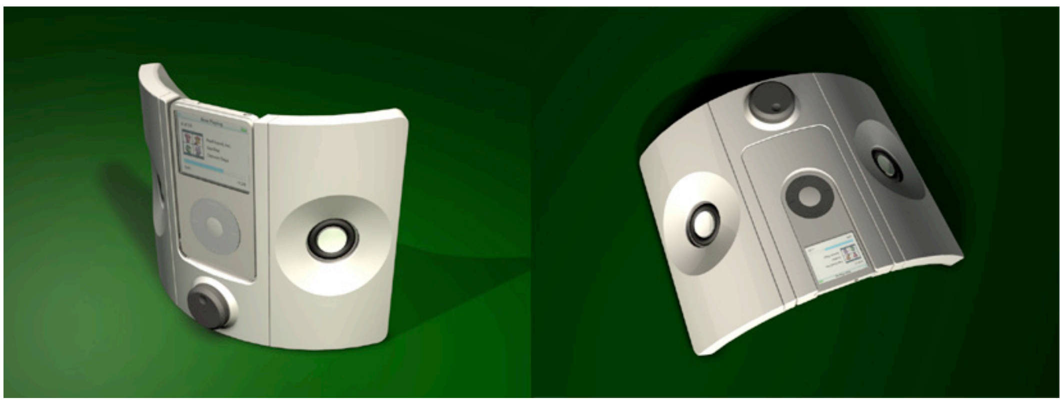

Figure 23: Final design of stereo

When comparing the previous final designs with the new design, there are a number of sustainable, aspects to the new design. The enclosure is made from an estimated 20% recycled ABS, as recommended by the vendor. The design has additional functionality. It now works with two iPod models and could be adapted to future iPod models as well as to the Microsoft Zoon. The circuit board and other potentially hazardous materials are no longer trapped inside the enclosure. It was designed for ease of disassembly rather than plastic welding. This also allows the plastic to be reintroduced to the technological cycle as uncontaminated ABS. It is also possible for the speaker drivers and/or the circuit board to be reclaimed and possibly reused in a second life. The unit contains four AA rechargeable batteries. The original product utilized non-rechargeable batteries. The can be powered or recharged by taking advantage of the power brick supplied by Apple with each iPod or a computer's USB port. This eliminates the need to supply a power adapter.

There are additional costs compared to the earlier versions. Although complete cost information is not available, the original stereo's cost allowed for a $29.95 retail price. There are four additional parts, but very little additional material compared to the earlier versions. The extra parts can be attributed to the modular nature of the design. There is also additional cost in the mechanical fasteners. These additional costs are offset by the extended life of the product, the additional functionality, and the lack of need for a power adapter. Initial and incomplete quotes for the new design also allow for a $29.95 retail price. The per unit enclosure cost is approximately $9.00, with the electronics cost under $4.00. One assumption is that the electronic may drop up to 25% due to the lack of need for a power adapter. Ultimately, the overall cost difference is negligible while providing a product with less negative impact on the environment.

Conclusion

A quote from *Cradle to Cradle* speaks to the need for an easy to understand and implement sustainable design methodology, "Once you understand the destruction taking place, unless you do something to change it, even if you never intended to cause such destruction, you become involved in the strategy of tragedy." (44)

There are a number of valuable resources addressing the environmental impact of products. They are broad and encompass the entire product development infrastructure, placing importance and responsibility on government, executives, suppliers, engineers, designers, marketers and the consumer. Unfortunately, not all those involved are ready to assume responsibility. Environmental concerns are often viewed as an afterthought or placed last on a list of priorities. It is important that those who are concerned and ready to take responsibility have the ability to make a difference.

The role of the individual industrial designer can be both very limited and very critical to the environmental impact of a product. Depending on the circumstances, designers may be able to completely alter the environmental impact of the product by applying creative problem solving to multiple environmental strategies. More likely, however, proactive individual designers will only be able to address a minimal number of environmental strategies. Even if the designer is only able to provide for an easy means to disassemble a product, it could prove to be a significant improvement.

There are an increasing number of companies providing examples of sustainable solutions as well as the potential to increase profitability and consumer loyalty. These examples can serve as incentive for executives and managers to follow suit. There is also increasing awareness and pressure being placed on government representatives that will likely lead to more stringent environmental regulations that could lead to mandatory take-back programs and increasing pressure on usage efficiencies.

It is important for designers to continue to research successful benchmarks and trends. Successful implementation of environmental solutions may hinge on the designer's ability to sell the solutions. Designers should arm themselves with as many successful precedents as possible to sell the solutions to decision makers that are always weary of taking unnecessary risks.

As environmental awareness is increased and more pressure is applied to decision makers, the opportunity to make significant improvements should increase. As environmental mandates trickle from the top down from government regulation to company-wide adoption, designers will need to know how to implement environmental strategies. As the research shows, there are currently serious gaps in the designer's toolbox to do so.

The roadmap methodology developed within this thesis serves to provide designers the ability to make incremental improvements without being directly tasked to do so. It begins with a very broad look at many strategies, but as designers assess their influence and opportunities, their focus is narrowed to the strategies that are most important for them to explore, allowing them to create a more effective solution. By isolating specific sustainable strategies at specific stages of the design process, designers are able to pursue effective solutions in a time efficient manner, something any organization would find hard to argue against.

An additional advantage of applying this methodology is that designers will be better prepared once they find themselves within an organization with an environmental mandate. With the experience applying this methodology to multiple design projects, a designer will likely stand apart from those who have not and create possible opportunities for advancement.

Ultimately, industrial designers approaching sustainability from the ground level adds another front to the challenge of preserving mother nature's bounty for future generations. This methodology provides an easy to understand roadmap, encouraging designers to do just that.

Need for Continued Study

To date, there is no cure-all strategy that can be applied across the board. The pursuit of the "next industrial revolution" will require the effort of many. There is a great deal of research within large organizations going into addressing environmental issues. New solutions and strategies are emerging at an increasing rate. They include the development of less harmful materials, quick disassembly methods, and successful reuse strategies. Any methodology addressing sustainability will likely need to be revised to include the latest and most effective strategies, materials, etc.

Additionally, each of the individual strategies needs further development. Most of the strategies are simple checklists of what to avoid or how to minimize impact. Ray Anderson's ultimate goal is to make Interface the world's first industrial company to attain sustainability and then to become restorative. "To me, to be restorative means to put back more than we take, and to do good to earth, not just no harm." (8) As visionaries such as Anderson move closer to their lofty goals, others will learn how they have done it, emulating and building upon their success.

Environmental strategies are evolving. As environmental responsibilities are aligned more specifically to certain professions, the proper adjustments should be made. The influence of the designer should continue to be evaluated. If there are strategies within this methodology that are never addressed by the designer, it should be removed in accordance with the goal of minimizing complexity.

The methodology needs further testing. By applying it to multiple design projects, industrial designers can evaluate the effectiveness of the individual strategies as well as the methodology as a whole.

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