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CREATIVE ECO-EFFECTIVENESS

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CREATIVE ECO-EFFECTIVENESS

by

Clara Cecilia Rios Velasco Urrutia, LDI

Report

Presented to the Faculty of the Graduate School
of the University of Texas at Austin
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To my husband and best friend Andrés, whose support and unconditional love make me want to become a better person every day.

To my parents, Consuelo and Jaime, my brothers, Jimmy and Iván, and to my wonderful and incredible family in Mexico and Spain. Even in the distance, their love and encouragement helped me to achieve this goal.

To my professors and classmates at UT. I could have not done it without their support, commitment, and guidance.

CREATIVE ECO-EFFECTIVENESS

by

Clara Cecilia Rios Velasco Urrutia, MFA

The University of Texas at Austin, 2010
SUPERVISOR: Kate Catterall

My research is focused upon what industrial designers can contribute in order to mitigate environmental problems often caused by their designs. The intent is to propose a procedure to integrate eco-effectiveness at the beginning of the design process, to consider it at each stage of the product's lifecycle, and to measure that product's environmental performance in order to make informed design decisions. At each stage the designer can follow this flexible process, which is intended to work in conjunction with individual creative methods while prioritizing the need for eco-effectiveness. The goal is to develop a procedure that is simple enough for designers to use every day and that could also provide means of verification, rather than relying on assumptions and good intentions.

I acknowledge that efforts from a single discipline are not enough. In order to address the environmental challenges we face today, collaboration among disciplines will be necessary, as well as a change of behavior and attitudes towards consumption. This is my contribution.

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"If we do not change our direction, we are likely to end up where we are headed."
- Chinese Proverb

Introduction

For decades, “going green” and being “environmentally conscious” were viewed as radical positions and therefore disregarded by the mainstream. Consequently, consumer society proceeded along a trajectory mapped out for it in the earlier part of the 20^{th} century. However, over the last ten years, the importance of sustainable patterns of growth has increased significantly, and today, sustainability and the environment are viewed as pressing issues affecting every sphere of society and politics.

The methodology I was taught as an industrial design undergraduate was very rigorous, and mostly client/industry oriented. There was a focus on analyzing production cost, target markets, competition, etc. but the social context and potential environmental impacts of products was rarely discussed. In 2004, when I traveled as an exchange student to Spain, I became more aware of environmental issues and the ways in which environmental degradation will affect our lives in the generations to come. I also learned how designers might contribute to either the problem or the solution. This helped me decide to try to become part of the solution.

As a graduate student in Design at the University of Texas, my research has been focused on environmental issues such as climate change, degradation of ecosystems, and the consequences in our everyday life. But most importantly, I have realized that there is no single solution to these problems and that it requires local collaboration to achieve a global solution. There are no borders for the effects of climate change, isolated efforts from some countries might help but will not solve the issue. As a designer, researching environmental problems and possible solutions can be overwhelming and the scope of the problem has made me feel powerless at some points in my research. In consequence, I decided to step back and focus on what I could do as an industrial designer.

In assessing the precedents for environmental and social activism in relation to the practice of Industrial design, I referenced the work of Victor Papanek, William McDonough, and Anne Leonard, I investigated Natural Capitalism, Biomimicry, and the Okala guide among other sources that influenced how I now understand Ecological design. I learned about eco-effective practice and established that I wanted to apply it from now on. However, when I tried to practice eco-effectiveness in conjunction with my personal creative methods, I encountered a major problem: I felt that I was guessing and basing my design decisions on assumptions rather than information and the actual environmental performance of materials, processes, and the resulting product. To approach this issue, I looked for the available tools to help designers make better design decisions. In my research, I found that to date, most of the available Life Cycle Assessment (LCA) software is operated by engineers, focuses on a post-production analysis, and is difficult to integrate from the beginning of the design process. This makes it more complicated and costly to implement design changes that limit the ecological impact of a product before it is mass-produced. For these reasons, designers find themselves getting frustrated with an ineffective, time-consuming method of evaluation. They are apt to abandon their efforts and simply select a known renewable or recyclable material, hope it is greener than the alternatives and hope that it can be marketed effectively as a green product, a process that has come to be known as “green-washing”.

The focus of my research, therefore, is to propose a method to integrate eco-effectiveness at each stage of the product’s life cycle, from the beginning of the design process, and to propose a way to measure it. My methodology consists of a series of steps for the seamless integration of eco-effectiveness into the design process, and in my research, I performed two case studies to test this method. My intention is that at each stage the designer can follow a flexible eco-effective process that works in conjunction with his or her individual creative methods.

I believe there is an opportunity to change a myopic outlook in which we think of design as a style or an artifact dictated by market trends instead of thinking of design as a system of process within systems. There is an increasing need in design practice to shift this paradigm towards a holistic approach to industrial design; our responsibility is not only to design the artifact, but also to design the system in which this artifact is conceived, used and disposed, which is whole-system design. John Ehrenfeld defines Sustainability in his book *Sustainability by Design* as "The possibility that human and other life will flourish on the planet forever", "flourishing" being an emergent property that only appears when the whole system is functioning properly.[1]

This research focused on what industrial designers can contribute to solving environmental problems caused by consumerism. However, I acknowledge that efforts from a single discipline are not enough; in order to solve the environmental challenges we are facing today, we need collaboration among disciplines as well as a change in behavior of society and consumers.

[1] Ehrenfeld, John R. *Sustainability by Design: A Subversive Strategy for Transforming Our Consumer Culture.* New Heaven and London: Yale University Press, 2008.

Chapter 1: Environmental Issues

It is now certain that climate change and environmental degradation will affect ecosystems, society and business; this may happen abruptly and its effects could be devastating.[2] According to the Intergovernmental Panel on Climate Change in 2007, some of the projected changes this century include more hot days, more frequent heavy precipitation, intense tropical cyclone activity, more areas affected by drought and a rise in sea levels. It is becoming clear that these changes will profoundly affect ecosystems leading to the loss of habitat and species. Moreover, these changes will also mean higher energy demand for cooling and declining air quality in cities; an increase in water demand; an increase in insect infestation; floods that disrupt settlements, commerce, transport and societies, property loss; and shortages of water.[3]

Slowly, and several years overdue, the general population seems to be realizing the importance of environmental conservation and how the degradation of the environment might affect their lives. People are also demanding better strategies, products and practices from companies and governments. Websites like GoodGuide, Skin Deep, and Climate Counts encourage companies to be more open about their environmental practices by ranking them based on their environmental, health and social impact. The new era of transparency awards major points in reputation and image to companies that are willing to be more open.[4] This desire for openness of information allows consumers to be more informed and aware of the environmental performance of products, therefore, more capable to make better choices for the environment when selecting products.

A push from the bottom-up has led to the mobilization in a number of different sectors: governments around the world are seeking to mitigate the effects of climate change and are implementing regulations on emissions; companies are

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[2] Schwartz, P. "Investing in Global Security." *Harvard Business Review OnPoint*, Spring 2010: 18, 19.

[3] Schwartz, P. "Investing in Global Security." *Harvard Business Review OnPoint*, Spring 2010: 18, 19.

[4] Goleman, D. "Winning in an Age of Radical Transparency." *Harvard Business Review OnPoint*, Spring 2010: 9-10.

improving their practices to reduce costs and improve their public image; professionals, from the business world to the sciences, are trying to improve their practice and follow a more sustainable route. Designers now have the opportunity to reassess their methods and realize the implications of the artifacts they design and, most importantly, what they can do to change their practice.

Chapter 2: Changing my design practice (Precedents)

The following precedents influenced my early research and challenged me to change my design practice. They range from my initial encounter with ecological and ethical design, the recognition of a competitive opportunity, innovative methods of practicing interdisciplinary design, and the discovery of eco-effectiveness.

Victor Papanek

In his book *Design for the real world*, Victor Papanek wrote:

> There are professions more harmful than industrial design, but only a few of them… by creating whole species of permanent garbage to clutter up the landscape, and by choosing materials and processes that pollute the air we breathe, designers have become a dangerous breed.[5]

In 1971 Papanek saw designers as the creators of the future landfill, and advocated for the adoption of a morally responsible and holistic approach to design. Papanek was a strong advocate of human-centered design and vernacular design. He was one of the first industrial designers to critically analyze design as a force for good, suggesting that commercial design was not necessarily the best way to design and questioning the common practices of designers at that time.

Papanek's ethics-driven design was deeply connected to an ethical management of resources and understanding a product's impacts on the environment. He was one of the first people to look into Life Cycle Analysis, exploring the idea that a product not only had an impact in the environment when it was disposed, but that we also needed to include the entire processes this product went through before getting to our hands.

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[5] Papanek, Victor. *Design for the Real World: Human Ecology and Social Change,*. New York: Pantheon Books, 1971.

Forty years later we have still not caught up with Papanek's "radical" way of thinking. Design for maximum profit still drives our work and most of the time ethical design loses priority to our concerns for the economic bottom line. There is a misguided perception that there is no market for people with real needs, as Papanek would describe it, but this assumption is far from reality.

Design for the Other 90%

According to the book *Design for the other 90%* by Cynthia E. Smith, 5.8 billion people have little or no access to most of the products and services we take for granted, like regular access to food, clean water, or shelter. That is 90% of the world's population. Designers have been focusing on serving the "needs" of only the 10% of the world population because only 10% is able to afford our products. However, Design for the Other 90% explores a growing movement among designers to design low-cost solutions for this "other 90%." finding unique ways to address the basic challenges faced by the world's poor and marginalized.[6] Smith's argument is that there is a huge market that has not been addressed and that there is in fact an opportunity to help the underserved and to make a profit along the way, if the products are targeted at the right price.

Why Green Manufacturing?

In his doctoral thesis Stephen Clune said:

> If Industrial Design students are to be motivated and engaged in DfS, sustainability needs to be presented as more than a responsibility; students need to see clear, feasible, future vocational opportunities in DfS. Hence DfS needs to be presented as an opportunity with explicit career paths for their future vocations. The proposed future opportunities expand from the product focus of Industrial Design.[7]

According to Clune's research, ethics and doing the right thing are not enough to engage young designers in a sustainable practice in design; students need to see a feasible opportunity in DfS. With this in mind, I argue that DfS is, by itself, a career opportunity. In his webinar "Why green manufacture?" Dr. David Dornfeld,

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[6] Smith, Cynthia E. *Design for the other 90%.* Paris: Editions Assouline, 2007.

[7] Clune, Stephen. "Developing sustainable literacy in industrial design education : a three year action research project enabling industrial design students to design for sustainability." Doctoral Thesis, School of Engineering, University of Western Sydney, Sydney, 2009.

a professor of mechanical engineering at the University of California at Berkeley, explained the reasons why moving to green practices should be of great importance for business leaders.

According to Dornfeld, previous manufacturing paradigms show the different shifts that have happened over time: from Crafts to Mass Production, from Mass Production to Flexible Production, from Flexible Production to Small Lot and from Small Lot to the one we are entering now: Sustainable Production[8]. For the most part, the catalyst for all these transitions has been the same: cost reduction.

Dornfeld proposes that we reduce cost by eliminating environmental externalities, such as toxic components and chemicals, and by closing gaps in the life cycle cost, for example reusing parts or recycling materials. He sees the present paradigm shift in manufacturing as an opportunity for companies to innovate and move their manufacturing process to a more sustainable practice.
According to Dornfeld, consumers are starting to realize how environmental problems are affecting, or are about to affect their lives, and they are demanding products that are eco-friendly. He argues that governments are also acting upon this notion and, even when the environmental impact costs are not yet embedded with the manufacturing chain, governments are moving towards that with regulations, fines, tax benefits, and other public policy tools.

With this in mind, companies are more interested now in a practice that plans for cost reduction in all the stages of their product's life cycle by being environmentally conscious. Therefore, if designers change their methods to design with the whole-system approach in a holistic manner, they will have a competitive advantage; hence, eco-effectiveness will become not only ethical but also profitable.

Biomimicry

Biomimicry, an ancient concept of applying nature's lessons to human design, has recently been re-introduced to scientific thought. Biomimics (people who practice biomimicry) believe that nature's solutions are sustainable and in

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[8] Dornfeld, David. "Why green manufacture?" September 17, 2009.

harmony with the ecosystem and can provide potential models for how we can live more sustainably.

According to Janine Benyus, founder of the Biomimicry Institute, Biomimicry is not *using* nature to solve problems; therefore, making fuel from corn is not biomimicry, but rather is a bioprocess and a type of domestication. Biomimicry is *learning* from nature, taking the elegant design principle from nature (borrowing the "recipe") to solve problems. For example, using CO2 as a building block to make cement is biomimicry.[9] Biomimics consult organisms to be inspired by an idea, be it a physical blueprint, a process step in a chemical reaction, or an ecosystem principle such as nutrient cycling. Borrowing an idea is like copying a picture: the original image can remain to inspire others.[10]

Biomimicry consists of bringing biologists to the design table and is a cross-disciplinary process, therefore, you cannot practice it by yourself. And while it may not be the only road to sustainability, if we look at nature for solutions, we can get a head start on the research that natural organisms have already done for what works in a sustainable world.[11]

Cradle to Cradle

In their book *Cradle to Cradle,* William McDonough (architect) and Michael Braungart (chemist) argue that the triple bottom line (Planet, People, Profit) can be achieved by being eco-effective. Unlike Victor Papanek's uncompromising view of ethical and moral design, McDonough and Braungart take a more optimistic and business oriented approach on the environmental issue. Papanek talks about an imminent destruction of our planet unless we minimize the use of resources and only design for people with real needs; in contrast, this book is about designing in a system of abundance, where the use of resources is not an issue.

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[9] Biello, David. "Cement from CO2: A Concrete Cure for Global Warming?" *Scientific American.* August 7, 2008. http://www.scientificamerican.com/article.cfm?id=cement-from-carbon-dioxide (accessed October 8, 2009).

[10] Biomimicry Institute. "Biomimicry Symposium." San Diego, 2009.

[11] Biomimicry Institute. "Biomimicry Symposium." San Diego, 2009.

Cradle to Cradle suggested that, by adopting an eco-efficiency strategy – meaning minimizing waste, pollution, and natural resource depletion - we are not addressing the environmental degradation for long-term success, since it seeks to make the current destructive system sustainable. Instead, the *cradle to cradle* approach suggests following nature's model, which is not efficient at all, but is effective. The goal of eco-effectiveness is to design systems that emulate the abundance of nature, where *waste equals food*.

To better understand the eco-effective concept, McDonough and Braungart refer to the cherry tree:

> Each spring it makes thousands of blossoms, which then fall in piles to the ground –not very efficient. But the fallen blossoms become food for other living things. The tree's abundance of blossoms is both safe and useful, contributing to the health of a thriving, interdependent system. And the tree spreads multiple positive effects –making oxygen, transpiring water, creating habitat, and more. [12]

Cradle to Cradle highly influenced me to define my position and to identify what I wanted to achieve in my design practice. However, being eco-effective raised questions in practice: It proved to be not as simple as McDonough and Braungart described in their book, since they do not explain *how* to integrate eco-effectiveness at the beginning of the design process or how to make sure an artifact *is* in fact eco-effective. Being eco-effective implies the idea that there is no need to measure the environmental performance of products since "waste equals food", therefore it does not matter how much is wasted. However I found that while "waste equals food" is appealing as a long-term ideal, in practice it is not easy to achieve and it will not happen overnight. Hence, until we are closer to this utopia, the only way to assure that our products are not only based on good intentions and that they are not doing more harm than good, is to evaluate their environmental performance. With this in mind, I have focused my research on integrating eco-effectiveness into the design process and finding a way to measure it.

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[12] McDonough, William, and Michael Braungart. *Cradle to cradle : remaking the way we make things.* New York: North Point Press, 2002.

Chapter 3: Principal problems when discussing eco-effectiveness

The main issues that I found in the practice of eco-effectiveness were:

1. How to **integrate** it in the design process from the beginning.
2. How to **measure** and evaluate the environmental performance of the whole-system.

Integration of Eco-effectiveness into the Design process

Eco-effectiveness must be defined by how the entire life cycle of a product is planned. Usually consumers are only aware of one small portion of the life cycle, and it is on the "visible" part that most designers focus their efforts: sales, use and sometimes distribution.

One of the main barriers to the practice of eco-effectiveness is the myopic approach when designing an artifact, planning only up to the sales stage instead of planning for the whole life cycle of the product. By looking at the "whole picture," designers can make better choices and plan for solutions of waste disposal, recyclability, recovery of materials, etc. This approach not only is better for the environment but also reduces production and waste costs.

Eco-strategies by Life Cycle Phase

Eco-strategies can be applied at all stages of a product's lifecycle while designing the whole-system. They are very intuitive, simple, and sometimes obvious design solutions and most experienced designers develop an eco-intuition over time. However, most design students and inexperienced designers do not have this intuition. To change this, I believe that the development of eco-intuition should be embedded in industrial design education, as is cost and market analysis. I have selected a list of useful strategies currently available for students from different sources – Okala guide (Figure 2), Greenfly (Figure 3) and Rueda Estratégica del Ecodiseño (Figure 4) – and I keep adding strategies to this list as I develop my eco-intuition.

CONCEPTION/INNOVATION
- Re-think how to provide the benefit
- Dematerialization of a product
- Simplify
- Serve needs provided by associated products by integrating different functions
- Anticipate technological change and build in flexibility for updating
- Provide product as a service
- Share among users
- Apply Biomimicry
- Use living organisms in product

EXTRACTION OF MATERIALS
- Uses clean materials: do not damage human health, ecological health or deplete resources
- Use minimal impact materials – require low energy to produce
- Use renewable and sustainable resources
- Use waste byproducts
- Use thoroughly tested materials
- Use recycled or reclaimed materials

MANUFACTURING
- Design to simplify production quality control
- Minimize manufacturing waste
- Minimize energy used in production
- Minimize number of production methods and operations
- Minimize number of components/materials
- Use alternative production techniques
- Use clean energy for manufacturing

DISTRIBUTION
- Reduce product and packaging waste
- Use reusable or recyclable packaging
- Use an efficient transport system
- Use local production and assembly
- Use effective distributions logistics

USE
- Minimize emissions/Integrate cleaner or renewable and sustainable energy sources
- Reduce/Eliminate energy inefficiencies
- Reduce/Eliminate material use inefficiencies
- Reduce/Eliminate water use inefficiencies

PRODUCT LIFETIME
- Build in user's desire to care for product long term
- Design for take-back programs
- Build in durability
- Design for maintenance and easy repair
- Design for upgrades
- Create timeless look or fashion
- Modular-flexible product structure

END-OF-LIFE
- Integrate methods for product collection
- Provide for ease of disassembly
- Provide for recycling (upcycling)
- Design re-use or "next life of product"
- Provide for reuse of components
- Provide ability to biodegrade
- Provide for safe disposal

Figure 1: Eco-strategies

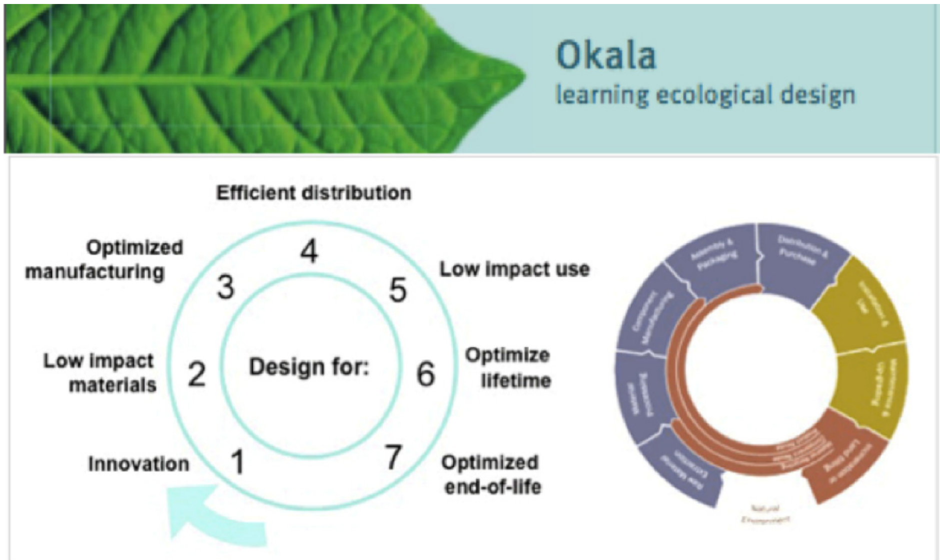

Figure 2: Okala's Ecodesign Strategy wheel

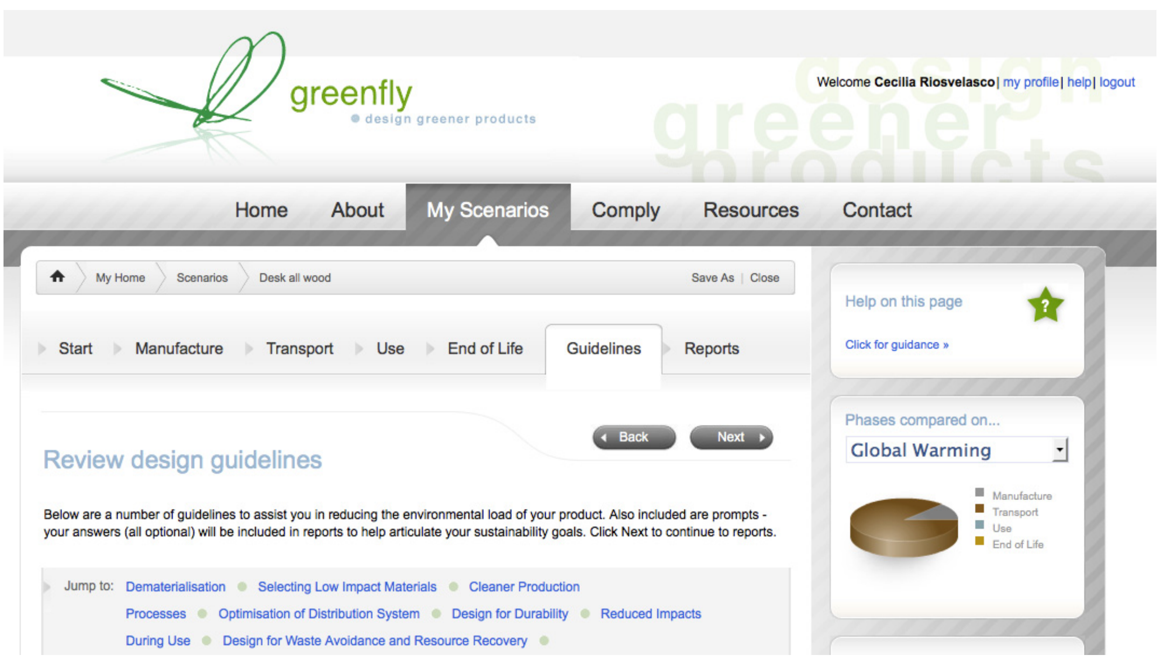

Figure 3: Greenfly design guidelines

Figure 4: Rueda Estratégica de Diseño, Canale 2005

Estimation and evaluation of environmental performance

The other challenge that I have encountered in the practice of eco-effectiveness is that of measuring and evaluating the environmental performance of a product. Measuring environmental performance is very important because design solutions based on assumptions rather than objective measurement methods, can sometimes create greater environmental damage than we might anticipate[13] since our intuition can be incorrect. For example, reusable grocery bags are the best choice for the environment; however, when deciding between paper and plastic the distinction is not as clear. Our intuition tells us that paper grocery bags are less harmful for the environment than plastic bags because paper is biodegradable, and paper bags are even advertised as the "green choice".

[13] IDSA. *Okala: Learning ecological design.* Second reprint. 2007.

However, in an article performing a holistic analysis of plastic bags vs paper bags, Muthu et. al[14] found unexpected results. Both paper and plastic bags are damaging for the environment at different points of their lifecycle in different categories. However when all the impact categories are accounted for, plastic bags were found to be better in terms of environmental impacts compared to paper bags. (See figure 5)

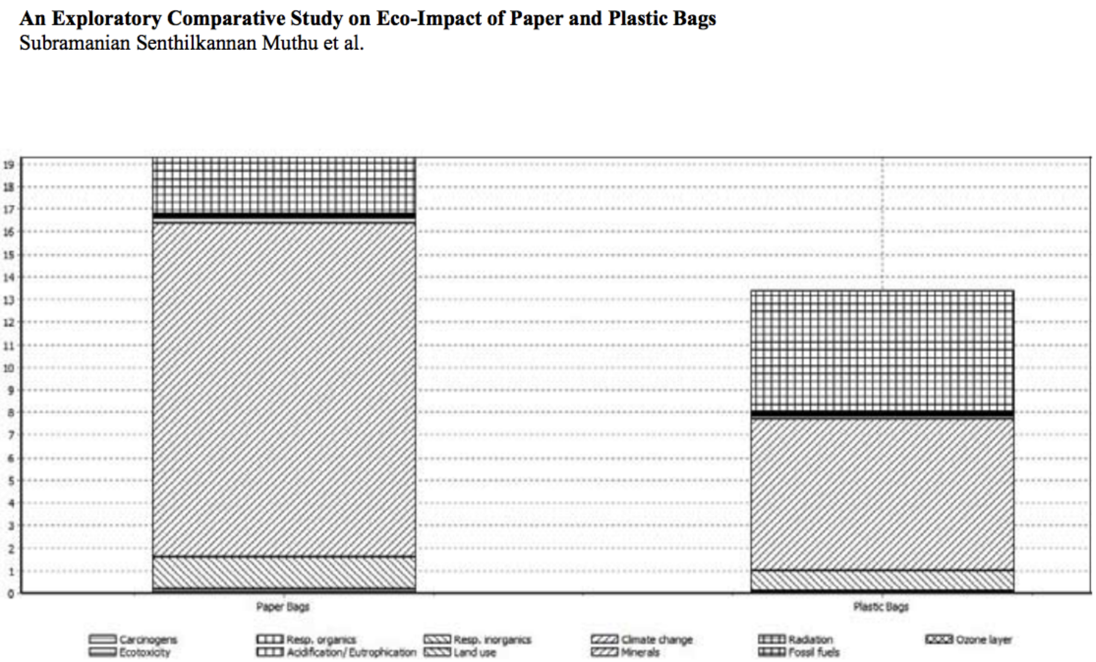

Figure 5: Single score value result - Paper vs Plastic

Just like economic performance, the environmental performance needs to rely on quantitative methods of evaluation to be as accurate as possible. The evaluation of environmental performance, however, presents deeper challenges and complexity since the transparency and accuracy of the information is not as straightforward as an economical evaluation. There can always be people that try to “adjust” the results to their advantage to show a better environmental performance, and therefore the proper use of this tool relies on the ethical code and values of the user. There are several environmental impact assessment

14 Muthu, Senthilkannan, Yi Li, Jun-Yan Hu, and Pik-Yin Mok. "An Exploratory Comparative Study on Eco-Impact of Paper and Plastic Bags." *Journal of Fiber Bioengineering and Informatics* 1, no. 4 (March 2009): 718 - 730.

methods; the most comprehensive and objective is the Life Cycle Assessment (LCA).[15]

Life Cycle Assessment (LCA)

LCA estimates a set of representative environmental impacts throughout all the phases of the life of a product. It enables the development of a multi-criteria environmental profile of a product and helps to identify the life cycle steps with the most significant environmental impacts. The LCA accounts for all known ecological and human health impacts of a product and process over its entire lifecycle.

The LCA is also the only method that is guided by the International Standards Organization (ISO) 14040 series standards.[16] This methodology is a holistic approach to ensure that any new design of an eco-friendly product improves the environmental performance overall and avoids impact transfer to another phase of life or another kind of pollution. This tool is continuously evolving and will continue to evolve both in accuracy and transparency of information, which is currently one of its key challenges.

LCA Software tools for designers

Being an inherently complex process, assessing environmental performance presents plenty of challenges for designers. Based on a survey conducted in 2006 most life cycle assessments analyses are carried out with dedicated software packages, the most popular software used were GaBi Sotfware by PE International and SimaPro by PRé Consultants.[17] However, both of these programs are focused on a post-production analysis and are usually used by engineers or scientists. In addition, they are complicated, time-consuming and specialized, therefore, difficult to integrate from the beginning of the design process. For instance, if the environmental analysis of a computer is done after it has already been designed, it will be complicated and costly to make design changes to limit the ecological impact.

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[15] IDSA. *Okala: Learning ecological design.* Second reprint. 2007.

[16] IDSA. *Okala: Learning ecological design.* Second reprint. 2007.

[17] Cooper, J S, and J Fava. "Life Cycle Assessment Practitioner Survey." *Journal of Industrial Ecology* 10, no. 4 (2006): 12-14.

Nonetheless, even with its challenges, LCA is, according to the Okala Guide, the most comprehensive and objective method for measuring the environmental performance of products (See figure 5). Therefore, rather than reinventing a measuring method, designers need to integrate the LCA to measure and evaluate a product's potential ecological impact, from conceptualization through to production – and use this information to guide design decisions along the way.

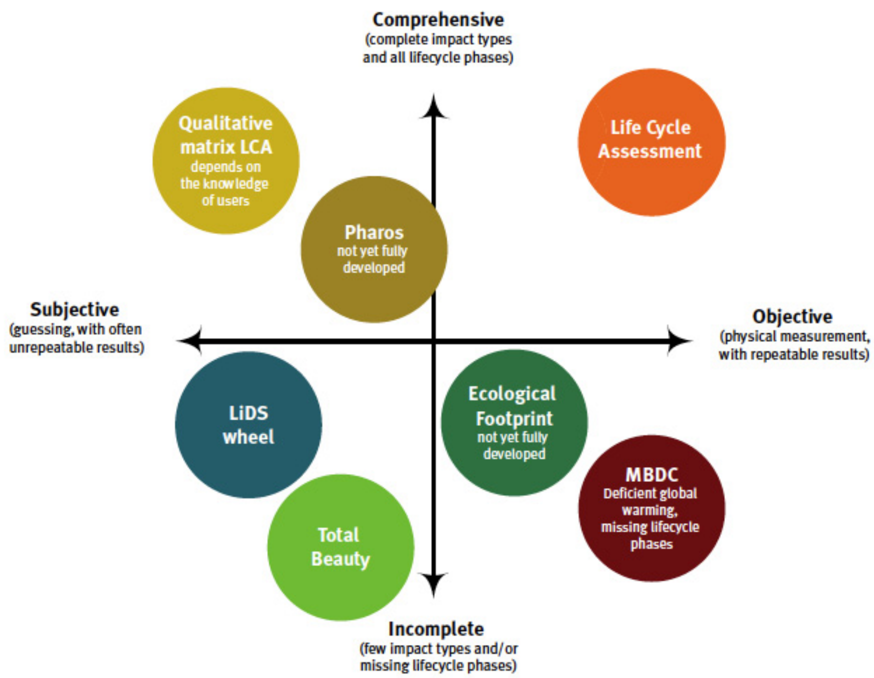


Figure 6: Environmental impact assessment methods (Okala guide, 2008)

Fortunately, software companies like PE International, PRé Consultants, and Sustainable Minds, among others, have realized the importance of making these tools accessible for designers, and have developed different versions to be used by designers. These versions have limitations compared to the "original" versions: they can be less accurate, the materials library might not be editable or as extensive and they have less flexibility.

To gain a better understanding of the available tools for measuring environmental performance that can be used by designers, I did an analysis of some of the available LCA software for designers.

Analysis of LCA Software for Designers

The analysis was performed on six different programs to evaluate their usability, accessibility, user friendliness, flexibility, affordability, materials and processes library, etc. The process of testing and evaluating the software was realized by running the tutorial projects that came with some of them. The analyzed features were: Developer and origins, platform (Windows, Mac or online), cost, materials and process library, units and data flexibility, user friendliness (user interface, navigation, learning curve, difficulties, etc.), and compatibility with other software.

For this analysis I assumed the practical position of a design student with no previous knowledge of LCA methodology, trying to analyze the environmental performance of a very simple design. The analysis was conducted on the following LCA software:

GaBi Lite

Developer and origins:

Developed by PE International from Germany, GaBi Lite Software was designed to be less complicated than the original GaBi so it could be easily used by people with no previous experience in complex LCA modeling.

Cost:

1800 USD for professionals and 450 USD for students.

Platform:

GaBi Lite is available for Windows systems only, which is a limitation since a lot of designers use Mac OS system.

Library:

In my analysis, I found GaBi professional has a very comprehensive and inclusive materials and process library, having one of the largest database available.

However, GaBi Lite offers only selected data from the PE-GaBi database and it cannot be modified or updated. In order to extend the materials and processes library you would need to upgrade to the original GaBi.

Units and data flexibility:

GaBi Lite allows for flexibility in units for metric and English systems, which can be very useful for analyses that are made outside the United States. It also allows for flexibility to select the source of energy, method to be used for the impact assessment, and the region for normalization of the impact assessment parameters.

User friendliness:

The user interface is not intuitive or straightforward unless you are familiar with similar software. GaBi lite requires time for the user to understand the logic followed in the interface. First, the input of information is done according to the physical structure of the product, only specifying name and weight using a process tree system (See figure 7). Then, the specifications of parts and components is added, however, unlike other software like Sustainable Minds where you can see an overview of all the phases of the lifecycle, in GaBi lite the lifecycle phases are separated and specified at different point of the analysis. This characteristic would not be a problem if the user were familiar with LCA software, however for an inexperienced user it has a steep learning curve and is difficult to learn it without any previous knowledge of any LCA Software.

Compatibility with other software:

GaBi lite is compatible with GaBi professional if an upgrade is desired and it allows for presenting the results in tables and diagrams and exporting the information to Microsoft Word.

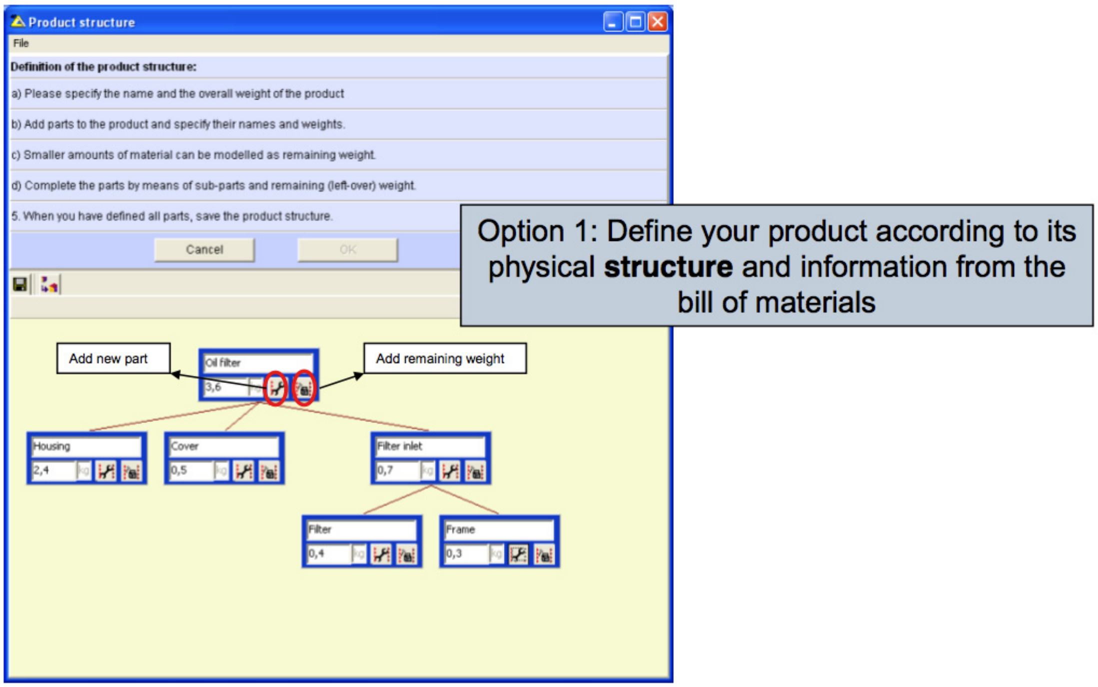


Figure 7: GaBi Lite Software

Eco-it

Developer and origins:

Developed by PRé Consultants in the Netherlands, Eco-it is the lighter version of SimaPro. Similar to GaBi Lite, this version was also developed to make LCA accessible for people with no previous knowledge, but more specifically targeting designers and taking the Design for Environment (DfE) approach.

Cost:

This software has a free 10-day evaluation version and the full version costs 143.27 USD.

Platform:

Same as GaBi Lite, ECO-it is also a Windows product. It may be run on other systems, such as Macintosh and Linux, using a Windows emulator. However, they do not offer technical support on these systems.

Library:

ECO-it comes with more than 200 scores for commonly used materials and processes. One of the best attributes of this software is that you can add and edit the materials library using the Eco-edit program, which is sold separately. However, the database can only be edited or expanded by LCA experts.

Units and data flexibility:

GaBi Lite allows for flexibility in units for metric and English systems, which can be very useful for analyses that are made outside the United States. It also allows for flexibility to select the source of energy, method to be used for the impact assessment, and the region for normalization of the impact assessment parameters.

User friendliness:

Eco-it is user-friendlier than GaBi Lite since it is has a better user-interface. Unlike GaBi Lite, Eco-it gives a holistic view of the life cycle of the product and also an entire view of the components of the product, which makes following the process more intuitive. It has a simple program structure with the four tabs (See figure 8) where you input the data:

1. The life cycle tab allows you to describe the product life cycle under investigation
2. In the production tab you enter the hierarchical structure of the product and specify the materials and production processes per part
3. In the use tab you can enter the energy and transport components
4. In the disposal tab you can specify the waste scenario for the product or for different parts and materials

Compatibility with other software:

On the evaluation of this software I could not determinate if Eco-it was compatible with SimaPro software based on the same methodology. The results are available to be printed but not exported to other software.

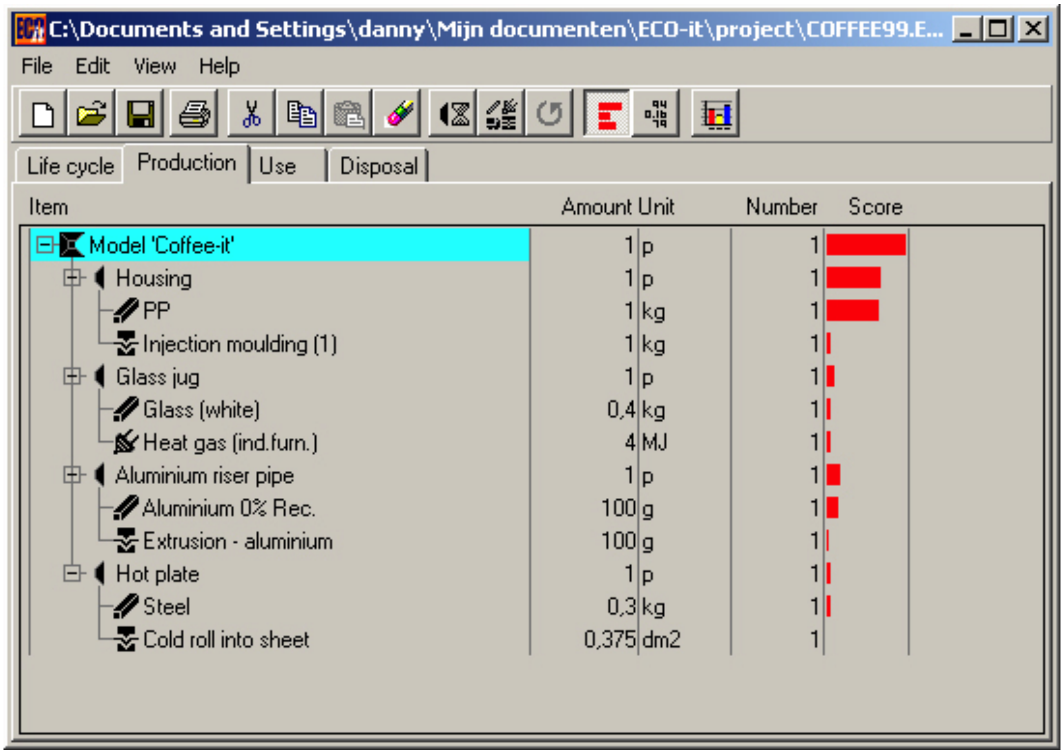


Figure 8: Eco-it screen shot

IDC LCA

Developer and origins:

Developed by IDC, which is one of the UK's largest, most well established and innovative product development consultancies, this software is online, free, and available to any user, no-registration required.

Cost:

Free

Platform:

Online

Library:

Very limited and the program only allows for five materials entries for the product and three materials entries for the packaging.

Units and data flexibility:

Only available in the metric system and the input of the data is too general. For example, if your product has electronic parts, instead of asking for the specific components of the electronic parts, it only asks for the mass of all electronic components.

User friendliness:

The LCA Calculator is a very simple tool and it was designed to help manufacturers take the first steps towards greener designs by assessing their product's carbon output. However, I found that this tool works best as an educational tool that explains the elements of LCA very straightforwardly. As a measuring tool, I believe it simplifies the process too much, has a restriction on the amount of processes and materials since it only allows for five entries, and it might give a misleading impression of what a true LCA analysis looks like. More than an LCA calculator, it seems a trouble-free way of explaining LCA to newcomers.

Compatibility with other software:

The results of the calculations can be emailed in .pdf format.

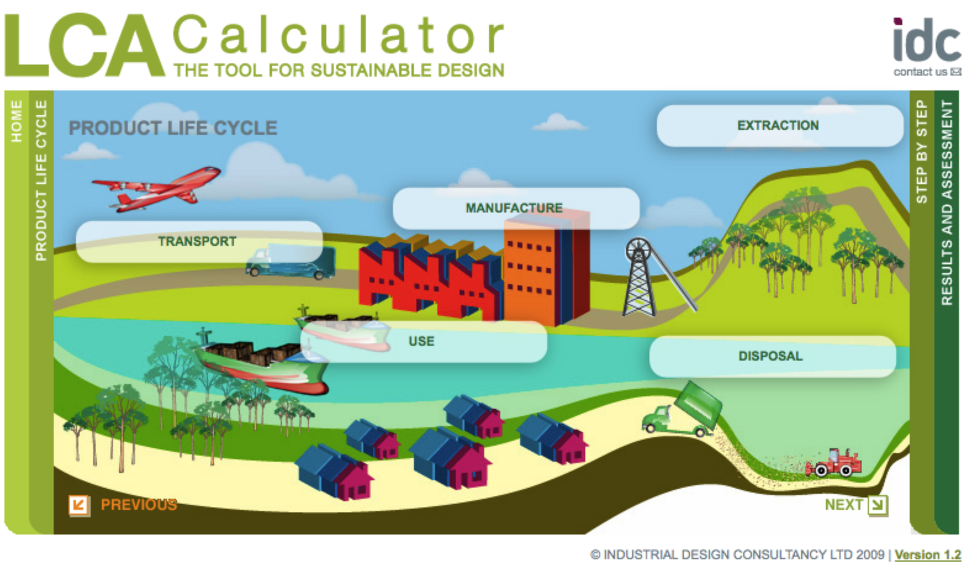


Figure 9: IDC LCA Calculator screenshot

Greenfly

Developer and origins:

The Centre of Design and RMIT in Australia developed greenfly with financial support from Sustainability Victoria, which aims to reduce the carbon footprint of product design.

Cost:

Free

Platform:

Online

Library:

Greenfly's library has a comprehensive library, however, the process and materials selections are too general. For example when selecting wood, it will not allow you to specify the type of wood in detail, only if it is hardwood, MDF, particle board, etc. (See figure 10). This limitation of materials and processes can make the results inaccurate and not useful in making design decisions.

Units and data flexibility:

The units are limited to the metric system and at some stages you need to make the conversions yourself, for example, while calculating transportation you need to convert to tonnes/kilometers. Also, the environmental performance score is not as easy to read since it does not have a single score but is divided in four categories: Global warming, water use, energy demand, and solid waste. While the separation of the categories might be an advantage for some scenarios, when making design decisions, it is easier to have a single score to compare.

User friendliness:

This software was the easiest to learn and understand of all the software analyzed. The user interface is very intuitive and it guides you through the process smoothly. It is also the most successful tool for integrating eco-strategies in the LCA process, giving you the opportunity to specify them in an environmental performance report. This qualitative information can be very useful for making eco-effectiveness decisions.

Greenfly promotes a learning dynamic by going one by one through its eco-strategies, providing you with the means to explain how the design is approaching those strategies and giving the user an opportunity to re-evaluate choices. When selecting a material it will give you some specifications you need to consider when selecting it. (See figure 10). Also, there's a small screen that will give you "tips of the day" with sustainable ideas to consider at a specific product's life cycle. Another attribute is the ability to include the cost of the product, which can be very useful while making design decisions, however, you cannot compare concepts side-by-side to be able to see how your design decisions affect the environmental performance of the different concepts.

Compatibility with other software:
Greenfly allows you to print the results of your analysis but it does not allow exporting the results to any other software.

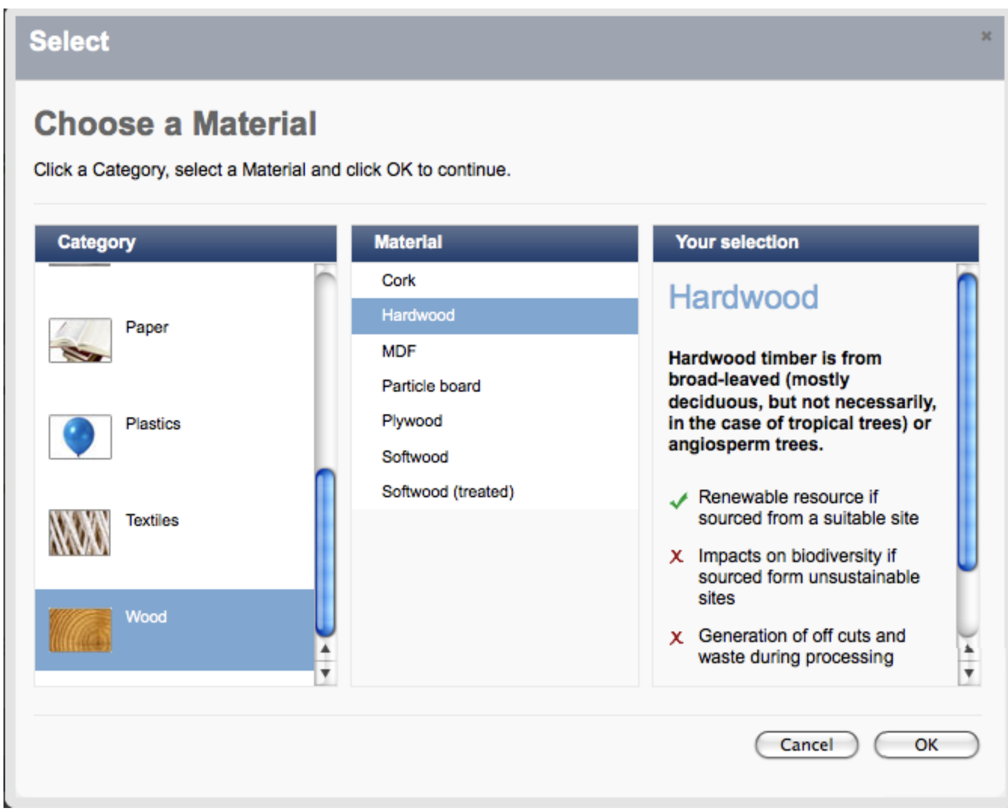


Figure 10: Greenfly material selection

Sustainable Minds

Developer and origins:

Sustainable Minds from the US is a company that wanted to make environmental sustainability accessible to mainstream product development and manufacturing, backed up by a credible methodology.

Cost:

Single user subscription:
Professional: 700 USD per year or 58 USD per month
Educator: 350 USD per year
Student: 10 USD per month

Platform:

Online

Library:

The library is comprehensive and is constantly being updated as users ask for new processes or materials to be added.

Units and data flexibility:

The units are only in the English system, which can be difficult to adjust to other regions outside the US.

User friendliness:

The software is web-based, intuitive to use, and includes online support, such as blogs, workshops, consulting, etc. Like Greenfly, it also has a learning dynamic. However the learning dynamic is not integrated in the calculation process but is more like another section of the program. Whereas Greenfly seems to have stopped its updates in 2008, Sustainable Minds keeps updating and developing new versions (currently on version 1.2) and adding more features. An important attribute of this software is the single-score indicator, which means that all the environmental impacts are summarized in a single number. It also allows for a side-by-side comparison among different concepts, which can be very useful for designers since it can make the decision-making process easier.

Adding the BOM takes time and can be somewhat frustrating since the information entered is not instantly updated. There is also inconsistency with the units: where for some materials the interface will ask you for weight, in others it will ask you for volume. Even with these weaknesses, I concluded that the Sustainable Minds software was the most useful (so far) for designers, since it has the tools for learning about EcoDesign (eco-strategies) and it allows for easy comparison among concepts.

Compatibility with other software:
Sustainable Minds is compatible with Autodesk Inventor, so users are able to upload a Bill of Materials (BOM) from the CAD program, making the process easier and less time consuming.

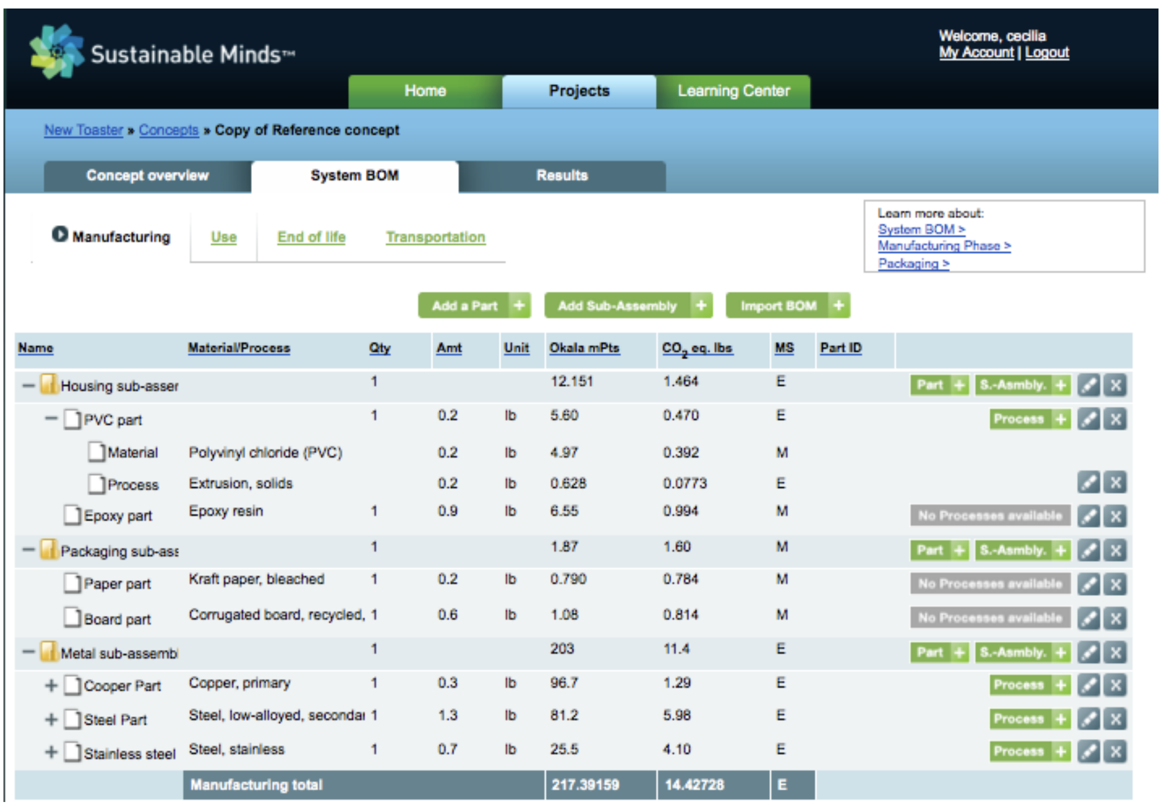


Figure 11: Sustainable Minds screenshot

Conclusions on existing LCA software for designers

The first challenge that I encountered when using LCA Software was that, by itself, it is useless for the designer in the early stages of the design process;

therefore, it does not work as a conceptual generative tool. You need to have a product concept to run through the analysis. If a designer only has sketches and ideas in his mind, the LCA will not be of any help to determine if his ideas are environmentally friendly or not.

Another challenge is that, in order to run your design proposal through the software, specific measurements of the artifact will be necessary such as weight or volume. Therefore, a basic 3D model will be necessary to make an estimate of these measurements.

Lastly, I concluded that while there are disadvantages compared with the engineer/scientific versions of the LCA software, such as accuracy and credibility. However, LCA software for designers offsets these limitations by being easier to learn, and more intuitive, but most importantly, by being able to make faster calculations, giving the designer the ability to make informed design decisions based on environmental performances.

LCA software needs to improve so that it promotes learning through the development of eco-intuition, promotes whole-system design, is user friendly and is not as time consuming. The existing available software has some qualities and attributes that, separately, are ideal for designers to use. For example, the learning dynamic in Greenfly, the single score in Sustainable Minds, and the integration of CAD software in Solid works sustainability. However, there is no one inclusive software alternative that has all the necessary attributes by itself.

Chapter 4: Potential for a measurable Eco-effective practice

With my research I concluded that the best way to integrate eco-effectiveness from the beginning of the design process was to take a whole-system approach and to utilize eco-strategies at each stage of the life cycle of a product. I also concluded that the best way to measure the environmental performance of products was to use LCA software tools for designers. I acknowledge the difficulties that the use of the LCA software presents. However, even with all the interaction faults/challenges of LCA, it is still the most comprehensive and objective method.

Miller et al. argue that LCA is not an adequate tool for the designer, because its usefulness is limited to an analysis of existing products or well defined products at the final stages of the design process, and it may generate confusion within the design team while restricting the capacity for innovation.[18] Their conclusion was that the LCA tool should be considered as a specialized tool handled by a specific player (the environmental actor, which would probably be an engineer or scientist). According to this paper, designers should not get involved in the measurement of environmental performance or try to integrate it in the design process because it requires another set of skills outside the designers' range. However, I believe that if we combine eco-strategies and design with a whole system approach from the beginning of the design process, LCA can be successfully integrated without losing creativity or the capacity for innovation.

With these issues in mind, I am proposing a procedure with a series of steps for the seamless integration of Eco-effectiveness into the design process. At each stage the designer can follow this flexible process, which works in conjunction with individual creative methods while prioritizing the need for eco-effectiveness. The goal of this method is to develop a process which is simple enough for designers to use every day and that could at the same time provide a

[18] Millet, D, C Ristagnino, C Lanzavecchia, R Camous, and Tiiu Poldma. "Does the potential of the use of LCA match the design team needs?" *Journal of Cleaner Production*, 2005.

means of verification that a product is in fact eco-effective, rather than relying on informed guesses and good intentions.

Projects: Creative Eco-effectiveness

The following case studies were designed with a whole-system approach, and to simplify the process so more designers can use it every day, the procedure consists of only four stages that occur before sending a design to production: Generate, Measure, Test, and Select. This process is intended to be cyclical: designers can verify the original project coordinates before moving on to the next stage. (Figure 11)

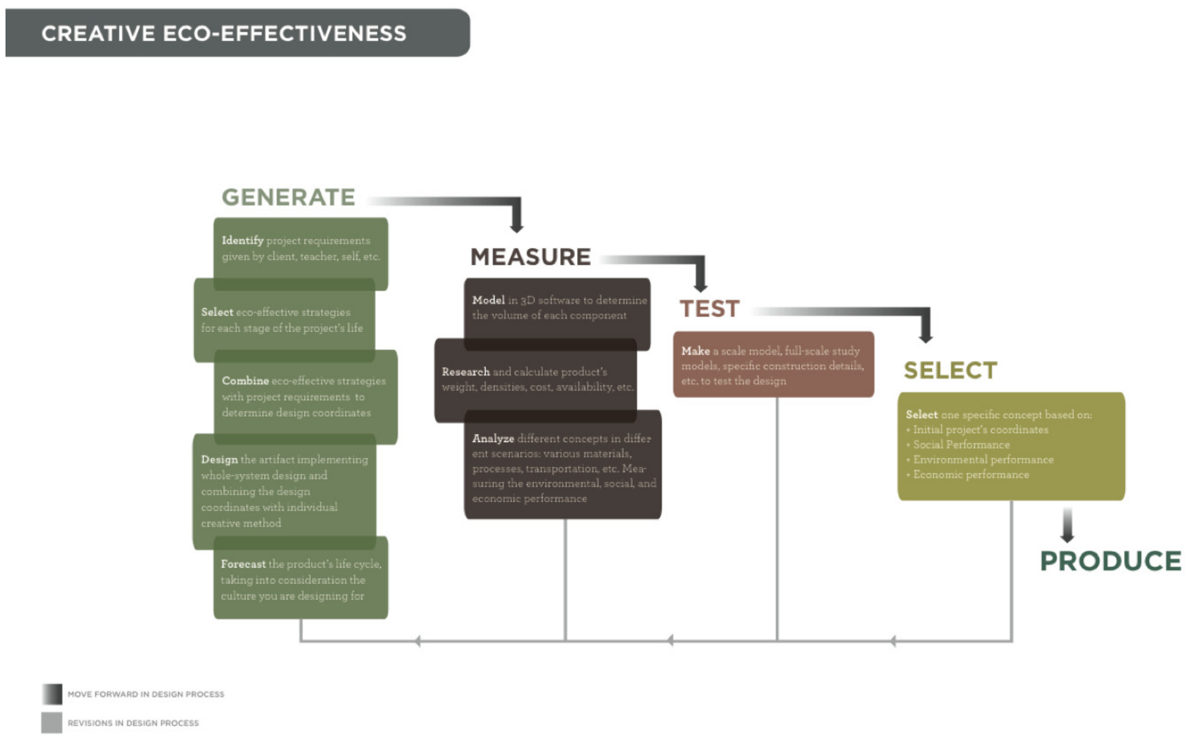


Figure 12: Creative Eco-effectiveness, graphic design by Emily Sawtelle.

Generate

At the "generate" stage the design coordinates are defined and the concepts are generated. This stage is composed of the following steps:

1. Identify project's criteria, which are usually given by a client, teacher, or are self-imposed.
2. Select eco-effective strategies for each stage of the project's life.
3. Combine eco-effective strategies with project criteria to determine design coordinates.
4. Design the artifact implementing whole-system design and combining the design coordinates with your individual creative method.
5. Forecast the product's life cycle, taking into consideration the culture for which you are designing.

Measure

At the "measure" stage, the concepts are tested and evaluated by alternating different scenarios. The categories to be measured are environmental performance, social performance, and economic performance. The environmental performance is measured by using existing LCA software (Sustainable Minds). The economic performance is measured consistently with the available information for each concept. The social performance is subjective and it requires research and knowledge about the culture for which you are designing. The steps to follow to simplify the measuring process are:

1. Model in 3D software to determine the volume of each component.
2. Research and calculate product's weight, densities, cost, availability, etc.
3. Analyze different concepts in different scenarios: various materials, processes, transportation, etc. measuring the environmental, social, and economic performance.

Test

The "test" stage consists of testing the design by making scale models, full-scale study models, specific construction details, etc.

Select

At this stage we are ready to select a specific concept to be sent to production based on the initial project coordinates, social performance, environmental performance, and economic performance.

The following case studies were developed to test this process.

Case Study 1: Desk for college students in developing countries

The first case study was designed to understand how the LCA software works and how to integrate the eco-strategies with the original project's criteria. The goal being to have defined coordinates that prioritized eco-effectiveness from the beginning of the design process.

The initial criteria for this project were to design a place where students from developing countries could do their schoolwork; an artifact that was easy to assemble, disassemble and re-assemble, affordable, and with better environmental performance than current solutions. In developing countries there are limited options for students to find furniture since there are no services like Craigslist, Goodwill or garage sales, so the alternatives they have is either to have furniture passed down from their relatives or friends, or to buy new furniture.

Passing down furniture is very common in developing countries and the re-use loop is very close and effective; there is usually someone you know who can use whatever you are disposing if it is in good condition. However, students moving from their hometowns to other cities, also known as "foraneos", usually do not have these resources in the "new" city.

The alternatives for buying new furniture are either buying high quality all-wood furniture, which is very expensive, or buying the less expensive, low quality furniture usually made of MDF or other composite wood. Because of the moving rate among "foraneos", this type of furniture does not last long because it gets damaged between moves. Usually the design for composite furniture is planned for assembly but not necessarily for disassembly and re-assembly.

For this reason the focus of this project was to assess if the current solutions were the most adequate for "foraneos" and to propose better alternative for the environment and for students. Taking into consideration that the common lifespan for this type of furniture is between four and five years, alternative materials like cardboard were analyzed. Also there was high emphasis on disassembly and re-assembly, as well as being lightweight and easy to move. This was a very simple project in which the social context highly impacted the final design selection. The environmental and economic performance also played a key role in the development of each concept.

Generate

1. Identify project's criteria, which are usually given by a client, teacher, or are self-imposed.

Time: 6 weeks
Cost: Under $70 to produce
Artifact: A place to do schoolwork
Other attributes: Easy to transport
Audience: College students in developing countries

2. Select eco-strategies for each stage of the project's life.

CONCEPTION/INNOVATION
- Re-think how to provide the benefit
- Dematerialization of a product
- Simplify
- Serve needs provided by associated products by integrating different functions
- Anticipate technological change and build in flexibility for updating
- Provide product as a service
- Share among users
- Apply Biomimicry
- Use living organisms in product

EXTRACTION OF MATERIALS
- Uses clean materials: do not damage human health, ecological health or deplete resources
- Use minimal impact materials – require low energy to produce
- Use renewable and sustainable resources
- Use waste byproducts
- Use thoroughly tested materials
- Use recycled or reclaimed materials

MANUFACTURING
- Design to simplify production quality control
- Minimize manufacturing waste
- Minimize energy used in production
- Minimize number of production methods and operations
- Minimize number of components/materials
- Use alternative production techniques
- Use clean energy for manufacturing

DISTRIBUTION
- Reduce product and packaging waste
- Use reusable or recyclable packaging
- Use an efficient transport system
- Use local production and assembly
- Use effective distributions logistics

USE
- Minimize emissions/Integrate cleaner or renewable and sustainable energy sources
- Reduce/Eliminate energy inefficiencies
- Reduce/Eliminate material use inefficiencies
- Reduce/Eliminate water use inefficiencies

PRODUCT LIFETIME
- Build in user's desire to care for product long term
- Design for take-back programs
- Build in durability
- Design for maintenance and easy repair
- Design for upgrades
- Create timeless look or fashion
- Modular-flexible product structure

END-OF-LIFE
- Integrate methods for product collection
- Provide for ease of disassembly
- Provide for recycling (upcycling)
- Design re-use or "next life of product"
- Provide for reuse of components
- Provide ability to biodegrade
- Provide for safe disposal

REQUIRED

DESIRED

Figure 13: Selection of Eco-strategies

3. Combine eco-strategies with project criteria to determine design coordinates.

DESIGN COORDINATES

PROJECT'S CRITERIA
Time: 6 weeks
Using Sustainable Minds software
Cost: under 1000 pesos to produce
Audience: College students in developing countries

REQUIRED STRATEGIES
- Simplify
- Minimize manufacturing waste
- Minimize number of components/materials
- Uses clean materials: do not damage human health, ecological health or deplete resources
- Use minimal impact materials – require low energy to produce
- Use renewable and sustainable resources
- Reduce product and packaging waste
- Provide for ease of disassembly

DESIRED STRATEGIES
- Use recycled or reclaimed materials
- Minimize number of production methods and operations
- Use local production and assembly
- Design for maintenance and easy repair
- Provide for recycling (upcycling)
- Provide ability to biodegrade
- Provide for safe disposal

Figure 14: Design coordinates

4. Design the artifact implementing whole-system design and combining the design coordinates with individual creative method.

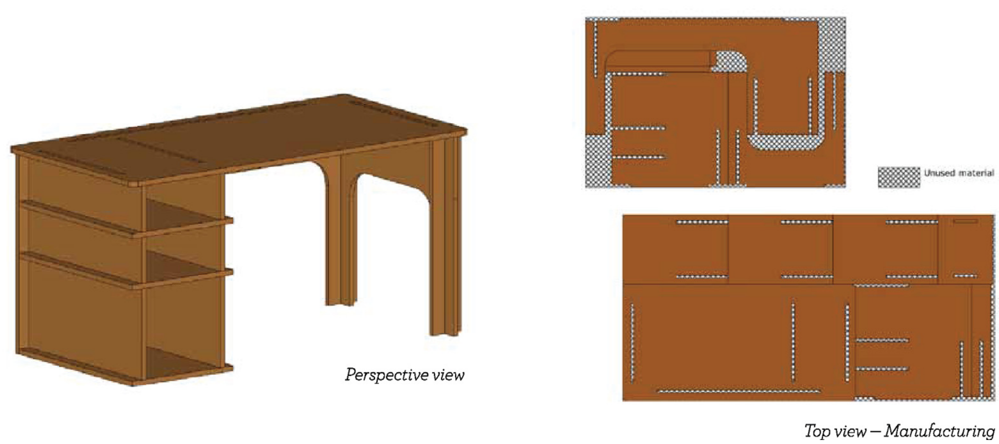


Figure 15: Design of the artifact

5. Forecast the product's life cycle, taking into consideration the culture for which you are designing.

FORECAST PRODUCT'S LIFE-CYCLE:

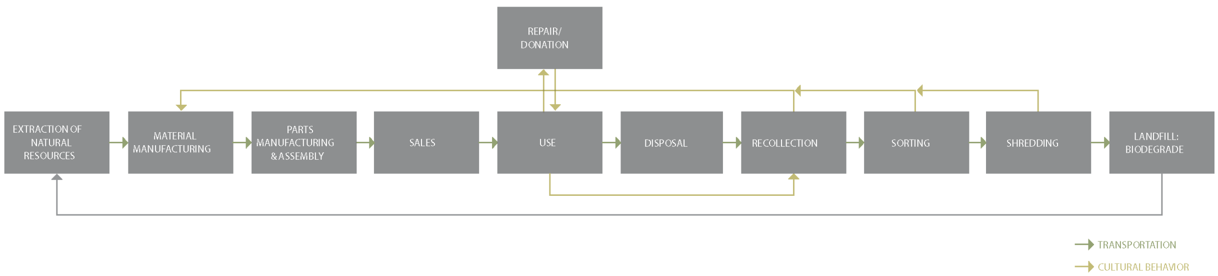


Figure 16: Forecast of product's lifecycle

Measure

1. Model in 3D software to determine the volume of each component. Color-coding or labeling each component can help to organize the bill of materials (BOM) while using the LCA Software.

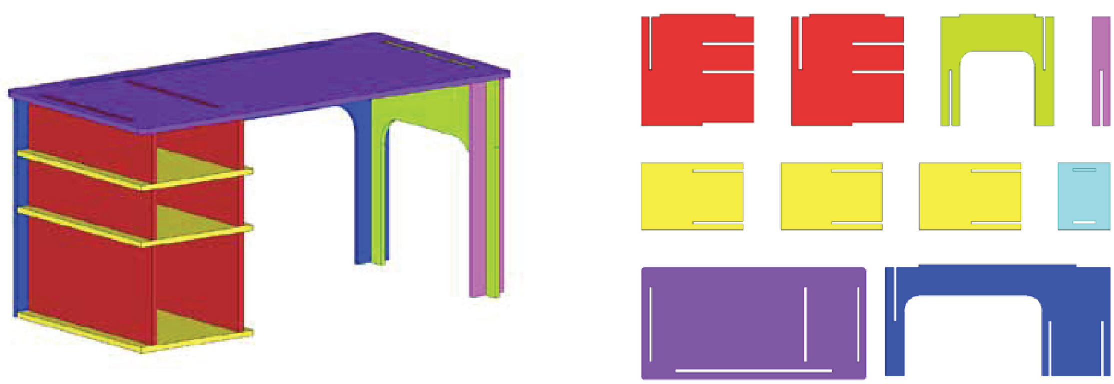


Figure 17: 3D Model of desk

2. Research and calculate product’s weight, densities, cost, availability, etc.

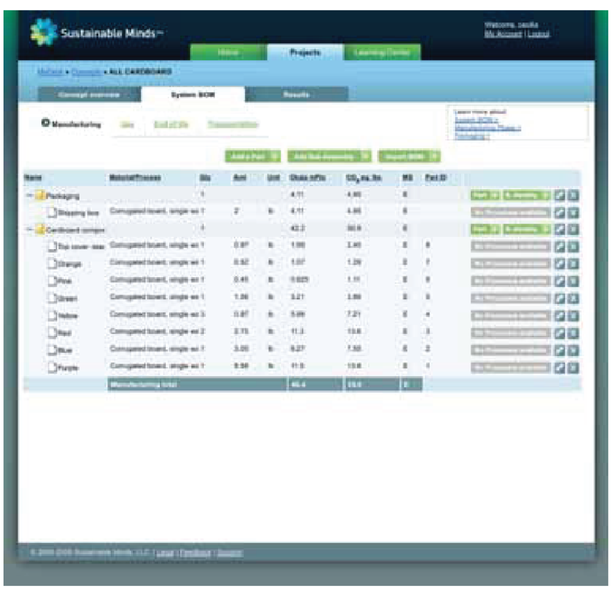
RESEARCH & CALCULATIONS
The weight can be calculated with the volume of each component and the material’s density

		VOLUME	CARDBOARD			PINE			LAMINATED TIMBER	
COLOR	NO. OF PIECES	VOLUME (FT^3)	DENSITY (LB/FT^3)	WEIGHT PER PIECE (LBS)	TOTAL WEIGHT	DENSITY (LB/FT^3)	WEIGHT PER PIECE (LBS)	TOTAL WEIGHT	VOLUME (FT^3)	TOTAL VOLUME
PURPLE	1	0.75	7.44	5.58	5.58	33	24.75	24.75	0.75	0.75
BLUE	1	0.41	7.44	3.05	3.05	33	13.53	13.53	0.41	0.41
RED	2	0.37	7.44	2.75	5.51	33	12.21	24.42	0.37	0.74
YELLOW	3	0.13	7.44	0.97	2.90	33	4.29	12.87	0.13	0.39
GREEN	1	0.21	7.44	1.56	1.56	33	6.93	6.93	0.21	0.21
PINK	1	0.06	7.44	0.45	0.45	33	1.98	1.98	0.06	0.06
ORANGE	1	0.07	7.44	0.52	0.52	33	2.31	2.31	0.07	0.07
					19.05			**86.79**		**2.63**

Figure 18: Material’s research

3. Analyze different concepts in different scenarios: various materials, processes, transportation, etc. measuring the environmental, social, and economic performance.

Data input to the LCA software



Environmental performance concept comparison

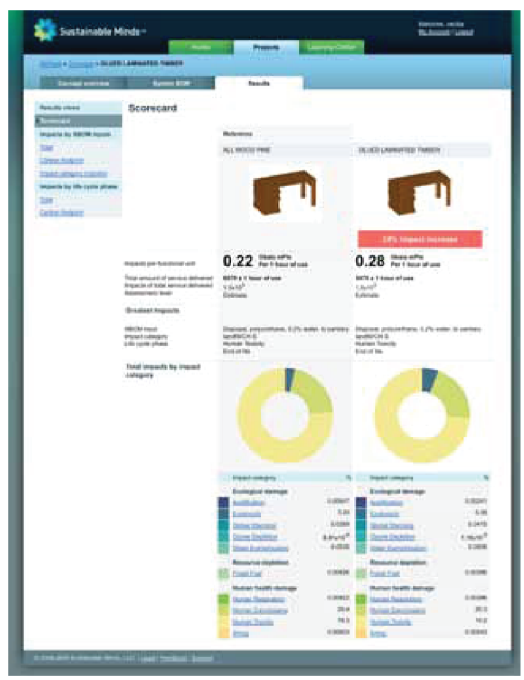


Figure 19: Environmental performance comparison

Test

1. Test the design by making scale models, full-scale study models, specific construction details, etc.

Figure 20: Photos of scale model – design in cardboard

Select

Select a specific concept based on initial project's coordinates, social performance, environmental performance, and economic performance.

CULTURAL BACKGROUND & CONSTITUENTS' BEHAVIOR

1. Mexico has a good cardboard recycling system
2. Foraneos (college students coming from other cities) cannot afford expensive desks which are usually heavier and more durable
3. Foraneos move a lot, therefore, a lightweight material would be easier to move along

DESIGN COORDINATES

1. It's cost under 1000 pesos to produce
2. It's easy to transport and move
3. It simplifies the assembly process
4. Does not use materials that damage human health, ecological health or deplete resources
5. Uses minimal impact materials
6. Uses renewable and sustainable resources
7. Minimizes manufacturing waste
8. Minimizes number of components/materials
9. Reduces the product and packaging waste
10. Provides for ease of disassembly
11. Uses recycled or reused materials
12. Minimizes number of production methods and operations
13. Can be repaired easily
14. Provides for recycling and upcycling
15. Provides ability to biodegrade
16. Provides for safe disposal
17. Uses domestic production and assembly

BEST ENVIRONMENTAL PERFORMANCE: CARDBOARD DESK

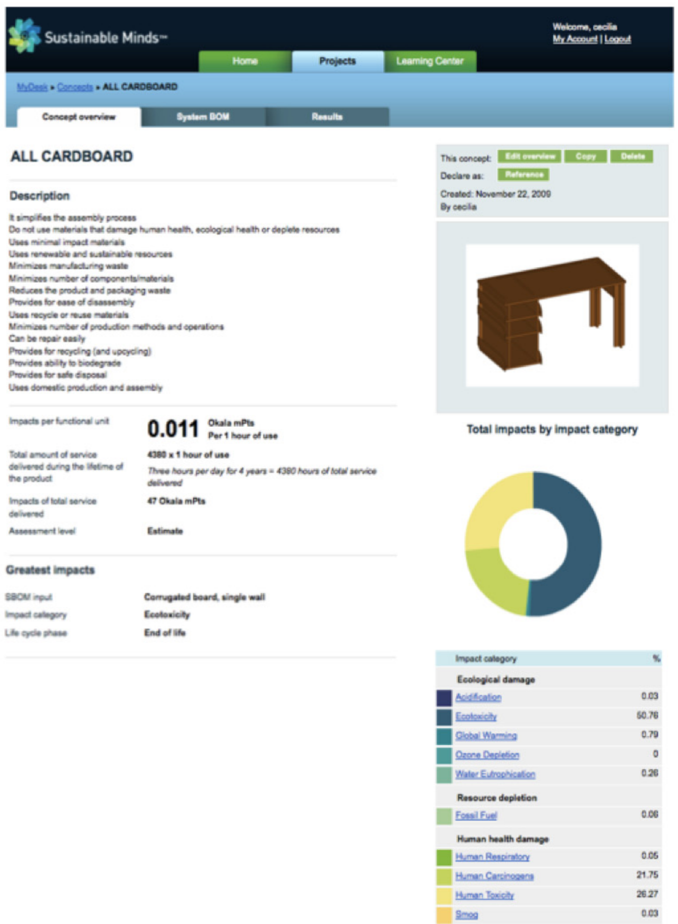


Figure 21: Selection of concepts

Results and outcomes: Case study 1

The concept selected was the one made in cardboard for its environmental, economical and social performance. It was the easiest solution for transportation, best environmental performance and most affordable compared to the other concepts made of MDF and pine. This case study was essential in better understand the challenges and difficulties of the process. It was a successful experiment since I was able to identify elements of the system that needed to be changed or improved. However, I realize that the design was relatively simple and did not require a lot of analysis: most of the questions were easily resolved. For this reason, I decided that another case study with a design of greater complexity was needed to test and perfect the methodology.

Case Study 2: Build your own table kit

In emergency management there are four phases: mitigation, preparedness, response, and recovery. This project is focused on aiding in the recovery phase, which aims to restore the affected area. The recovery phase comes after the response phase, which is concerned with immediate needs such as emergency evacuation, quarantine, mass decontamination, etc. Recovery efforts are primarily concerned with rebuilding destroyed property, re-employment, and the repair of essential infrastructure. However, the recovery phase can be slowed down by the lack of infrastructure, equipment, and material.

The table kit project proposes an alternative method of accelerating the production of furniture using scrap material retrieved from the disaster site, empowering the end-user. This project began with initial criteria of using scrap materials from a disaster zone in order to make new, economical furniture quickly and accelerate the recovery process. The initial criteria were combined with eco-strategies to generate the project coordinates and initiate the creative portion of the design process. Then, a series of potential concepts were measured by evaluating social, environmental, and economic performance. After the evaluation the most effective concept was selected for production.

Generate

1. Identify project's criteria, which are usually given by a client, teacher, or are self-imposed.

Time: 10 weeks.
Cost: Under $100 to produce.

Audience: People with access to scrap material but with no access to tools.

Artifact: Table frame that can be completed by the end-user using scrap material from disaster areas.

Materials: Wood and scrap material
Other attributes: Lightweight, easy to assembly, solidly built, durable.

2. Select eco-strategies for each stage of the project's life.

CONCEPTION/INNOVATION
- Re-think how to provide the benefit
- Dematerialization of a product
- Simplify
- Serve needs provided by associated products by integrating different functions
- Anticipate technological change and build in flexibility for updating
- Provide product as a service
- Share among users
- Apply Biomimicry
- Use living organisms in product

EXTRACTION OF MATERIALS
- Uses clean materials: do not damage human health, ecological health or deplete resources
- Use minimal impact materials – require low energy to produce
- Use renewable and sustainable resources
- Use waste byproducts
- Use thoroughly tested materials
- Use recycled or reclaimed materials

MANUFACTURING
- Design to simplify production quality control
- Minimize manufacturing waste
- Minimize energy used in production
- Minimize number of production methods and operations
- Minimize number of components/materials
- Use alternative production techniques
- Use clean energy for manufacturing

DISTRIBUTION
- Reduce product and packaging waste
- Use reusable or recyclable packaging
- Use an efficient transport system
- Use local production and assembly
- Use effective distributions logistics

USE
- Minimize emissions/Integrate cleaner or renewable and sustainable energy sources
- Reduce/Eliminate energy inefficiencies
- Reduce/Eliminate material use inefficiencies
- Reduce/Eliminate water use inefficiencies

PRODUCT LIFETIME
- Build in user's desire to care for product long term
- Design for take-back programs
- Build in durability
- Design for maintenance and easy repair
- Design for upgrades
- Create timeless look or fashion
- Modular-flexible product structure

END-OF-LIFE
- Integrate methods for product collection
- Provide for ease of disassembly
- Provide for recycling (upcycling)
- Design re-use or "next life of product"
- Provide for reuse of components
- Provide ability to biodegrade
- Provide for safe disposal

REQUIRED

DESIRED

Figure 22: Selection of Eco-strategies

3. Combine eco-effective strategies with project criteria to determine design coordinates.

DESIGN COORDINATES

PROJECT'S CRITERIA

Audience: People with access to scrap material but with no access to tools.
Artifact: Table frame that can be completes by the end-user using scrap material from disaster areas.

Time: 10 weeks.
Cost: Under $100 to produce.
Materials: Wood and scrap material
Other attributes: Lightweight, easy to assembly, solidly built, durable.

REQUIRED STRATEGIES
- Simplify
- Uses clean materials: do not damage human health, ecological health or deplete resources
- Use renewable and sustainable resources
- Use recycled or reclaimed materials
- Minimize manufacturing waste
- Minimize number of production methods and operations
- Minimize number of components/materials
- Reduce product and packaging waste
- Use reusable or recyclable packaging
- Build in durability
- Create timeless look or fashion
- Provide for ease of disassembly

DESIRED STRATEGIES
- Use minimal impact materials – require low energy to produce
- Use waste byproducts
- Use thoroughly tested materials
- Design to simplify production quality control
- Use local production and assembly
- Build in user's desire to care for product long term
- Design for maintenance and easy repair
- Design for upgrades
- Provide for recycling (upcycling)
- Provide for reuse of components
- Provide ability to biodegrade

Figure 23: Design coordinates

4. Design the artifact implementing whole-system design and combining the design coordinates with your individual creative method.

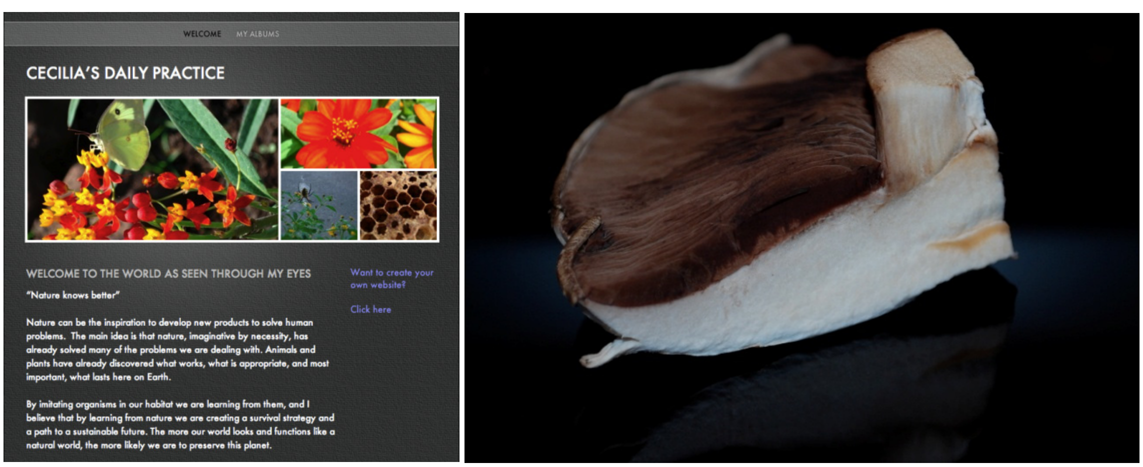
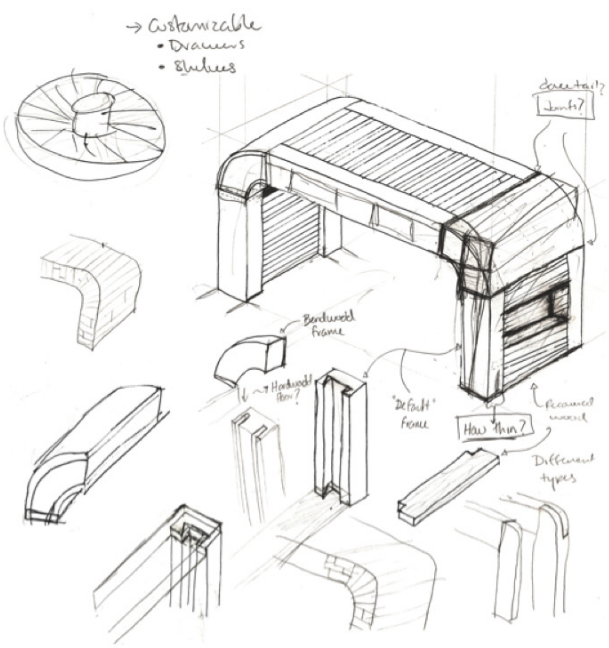
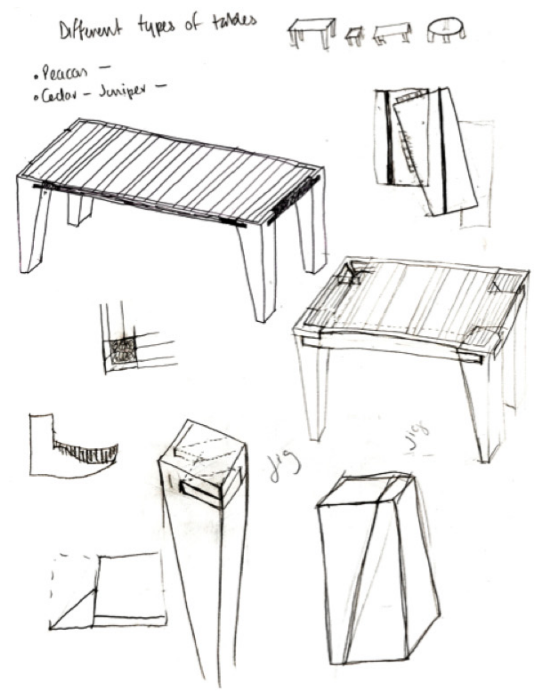


Figure 24: Source of inspiration – Mushroom



First design proposal: Too much material



Second design proposal: Less material

Figure 25: Design proposals

5. Forecast the product's life cycle, taking into consideration the culture for which you are designing.

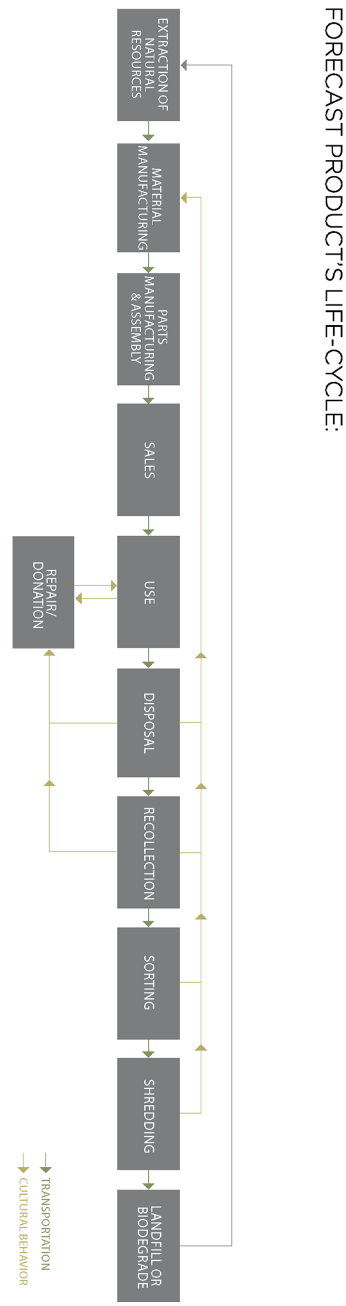


Figure 26: Forecast of product's lifecycle

Measure

1. Model in 3D software to determine the volume of each component. Color-coding or labeling each component can help to organize the bill of materials (BOM) while using the LCA Software.

Concept in Oak:

Oak is more expensive than poplar, however because of its density, it requires less material and it has less volume.

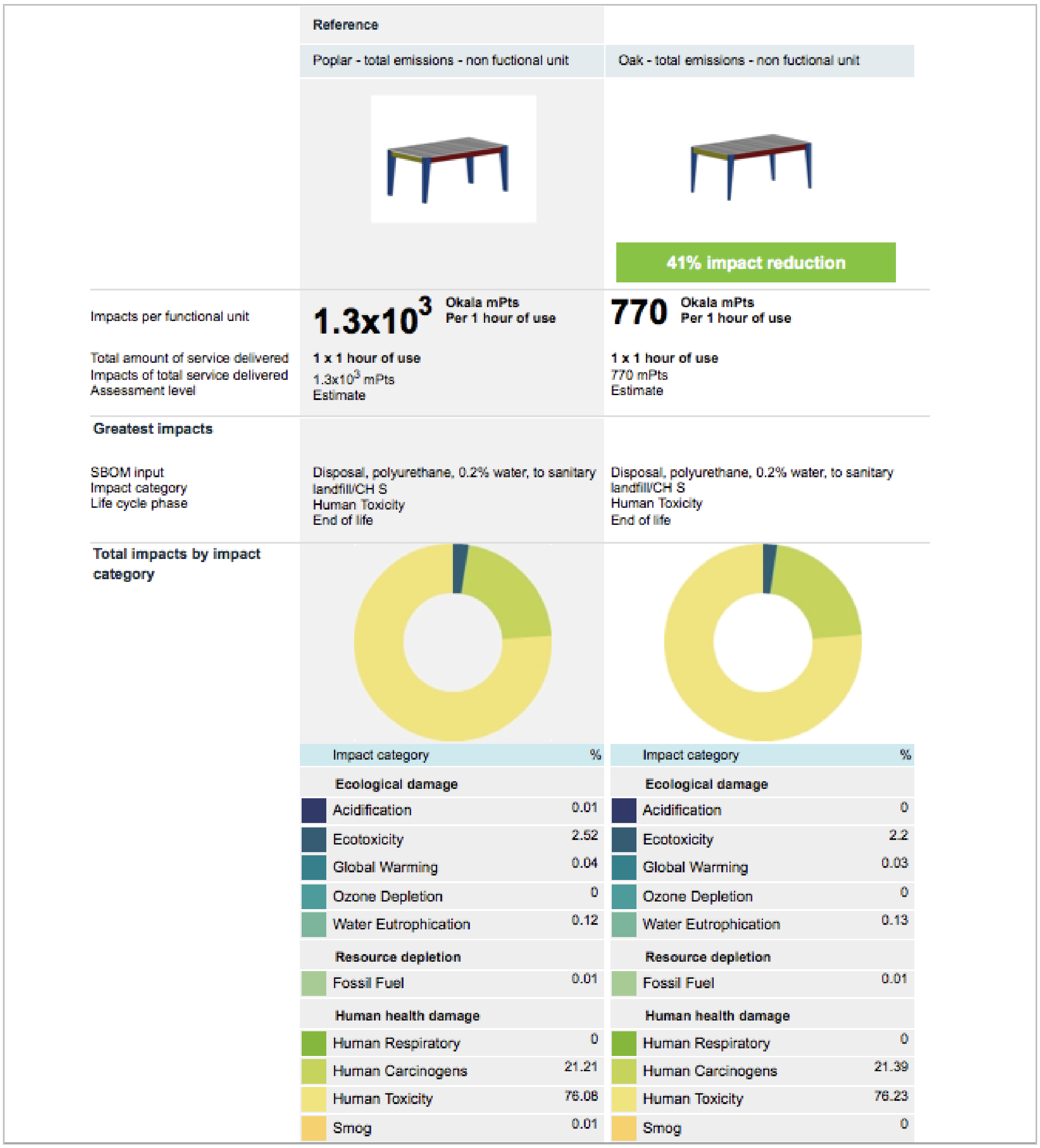
Figure 27: Concepts

2. Research and calculate product's weight, densities, cost, availability, etc.

		Design in Poplar			Design in Oak		
COLOR	NO. OF PIECES	VOLUME (FT^3)	WEIGHT PER PIECE (LBS)	TOTAL WEIGHT	VOLUME (FT^3)	WEIGHT PER PIECE (LBS)	TOTAL WEIGHT
Red	2	0.28	8.12	16.24	0.12	5.40	10.80
Green	2	0.15	4.35	8.70	0.05	2.25	4.50
Blue	4	0.16	4.65	18.56	0.07	3.14	12.60
				43.50			27.90

Figure 28: Material's research

3. Analyze different concepts in different scenarios: various materials, processes, transportation, etc. measuring the environmental, social, and economic performance.



	Reference	
	Poplar - total emissions - non fuctional unit	Oak - total emissions - non fuctional unit
		41% impact reduction
Impacts per functional unit	$1.3x10^3$ Okala mPts Per 1 hour of use	770 Okala mPts Per 1 hour of use
Total amount of service delivered	1 x 1 hour of use	1 x 1 hour of use
Impacts of total service delivered	$1.3x10^3$ mPts	770 mPts
Assessment level	Estimate	Estimate
Greatest impacts		
SBOM input	Disposal, polyurethane, 0.2% water, to sanitary landfill/CH S	Disposal, polyurethane, 0.2% water, to sanitary landfill/CH S
Impact category	Human Toxicity	Human Toxicity
Life cycle phase	End of life	End of life
Total impacts by impact category		

Impact category	% (Poplar)	% (Oak)
Ecological damage		
Acidification	0.01	0
Ecotoxicity	2.52	2.2
Global Warming	0.04	0.03
Ozone Depletion	0	0
Water Eutrophication	0.12	0.13
Resource depletion		
Fossil Fuel	0.01	0.01
Human health damage		
Human Respiratory	0	0
Human Carcinogens	21.21	21.39
Human Toxicity	76.08	76.23
Smog	0.01	0

Figure 29: Environmental performance comparison without functional unit

Economical Performance

	Part	# of pieces	Measurements: Thickness (")	Width (")	Length (")	Total Board feet	Total cost
Design in Oak	Legs	4	2	6	30	10.00	$45.10
	Rail 1	2	1 1/4	4	36	2.50	$10.20
	Rail 2	2	1 1/4	4	60	4.17	$17.00
							$72.30
Design in Poplar	Legs	4	4	6	30	20.00	$58.80
	Rail 1	2	3	4	32	5.33	$13.49
	Rail 2	2	3	4	58	9.67	$24.46
							$96.75

Figure 30: Economical performance evaluation

Social Performance

- Tool kit – half of the design – end-user "finish" the design by completing the table top with whatever material is available – sense of empowerment
- The end-user will care for the product long term (repair or upgrade) since it is something that he help to built.
- Design in oak is better socially because:
  - It's more durable
  - weights less (easier to ship & move around)
  - It's more affordable & uses less material

Figure 31: Social performance evaluation

Test

1. Test the design by making scale models, full-scale study models, specific construction details, etc.

Figure 32: Photos of scale model - design in oak

Select

1. Select a specific concept based on initial project's coordinates, social performance, environmental performance, and economic performance.

Initial project coordinates:

1. Production cost is less than $150
2. The artifact is completed by the end-user using scrap material from disaster areas
3. Accelerates the recovery process by allowing a faster production of furniture
4. It simplifies the assembly and disassembly process
5. Uses clean materials: do not damage human health, ecological health or deplete resources
6. Uses renewable and sustainable resources: FSC Certified
7. Uses thoroughly tested materials: Oak
8. Uses recycled or reclaimed materials from disaster zone
9. It is designed to simplify production quality control
10. Minimizes manufacturing waste
11. Minimizes number of production methods and operations
12. Minimizes number of components/materials
13. Reduces product and packaging waste
14. Uses reusable or recyclable packaging: cardboard
15. Uses combination of global and local production and assembly
16. It has build in user's desire to care for product long term since it is something they helped to build
17. Build in durability: oak
18. It is designed for maintenance and easy repair
19. It is design for upgrades: the table top can be updated
20. It has a timeless look and fashion
21. Provides for ease of disassembly
22. Provides for recycling by avoiding glues and hardware
23. Provide ability to biodegrade

Best social performance:
The design in oak is more durable, weight less making it easier for shipping and moving, and is more affordable

Best environmental performance:

	Reference Poplar - total emissions - non fuctional unit	Oak - total emissions - non fuctional unit
		 41% impact reduction
Impacts per functional unit	$1.3x10^3$ Okala mPts Per 1 hour of use	770 Okala mPts Per 1 hour of use
Total amount of service delivered	1 x 1 hour of use	1 x 1 hour of use
Impacts of total service delivered	$1.3x10^3$ mPts	770 mPts
Assessment level	Estimate	Estimate

Table in oak 41% impact reduction

Best Economical performance: Oak – About 25% production cost reduction

Figure 33: Selection of concept

Results and Outcomes: Case Study 2

The second case study was more complex than case study one and the results were more unexpected. The table-kit project was aimed to help the recovery phase in areas affected by disasters. One of the criteria was that it needed to be affordable (under $100) and that it needed to be lightweight for easy shipment to the disaster areas.

My initial response to these criteria was to use poplar for the design since it is affordable and has low density, which usually means it is lightweight. However, since one of the coordinates was that it required no-glue and no-tools for assembly, the joints and body of the frame needed to be resistant and solidly built. I made an alternative concept using oak instead of poplar and the results were unexpected. Even though oak is more expensive than poplar and has a worse environmental performance per square foot, because of its low density and high durability, it requires the use of less material; therefore, oak was a better design choice than poplar environmentally and economically. *My original "intuitive" design in poplar was not the best solution for this project and, because of the creative eco-effectiveness method, I was able to identify the best choice at an early stage of the design process.*

This case study highlighted the importance of analyzing the environmental performance of our designs in order to make informed design decisions.

Reflections on case studies

By doing these case studies I learned that the complexity of the LCA is directly proportional to the complexity of the product. The first case study was relatively simple since I used a small amount of variables for the design. For case study two, the design coordinates and variables represented a bigger challenge, but the solution was relatively simple and straightforward. Even though these two first case studies did not have many variables to run through the LCA software, the process for more complex projects involving a wide range of materials would be similar. I concluded that by combining eco-strategies with initial project criteria, designers are able to find eco-effective guidelines for the project from the beginning of the design process. By doing LCA analysis on alternative concepts, designers are able to make informed design decisions, instead of guessing or hoping they made the best environmental choice.

Conclusion

In recent years, sustainability has received more attention than in the previous three decades, with increasing publications, certifications, regulations, etc., which suggest that being environmentally conscious is no longer seen as an eccentricity. It also suggests a growing concern not only from scientists and biologists, but also from governments and the general public. However, even with this increased attention and concern, we are still far from a sound solution to the environmental problem. In the end, it comes down to ethical practice and being able to make design decisions based on reliable information and not only on good intentions.

My research focused on finding a method in which more industrial designers would apply a measurable eco-effective practice to their design process and gain eco-intuition over time, being able to make informed design decisions. I acknowledge the challenges the integration of a measurable eco-effectiveness practices presents and the complexity it embodies. For these reasons, I developed a procedure that simplifies this integration and tested this procedure by creating two case studies.

For future studies, I would like to pursue the development of a better design tool software that would integrate eco-effectiveness with the LCA methodology. I believe all the elements are already available in separate tools; the challenge is to take a “whole-system” approach and congregate these elements in one powerful yet simple tool.

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Vita

Clara Cecilia Rios Velasco Urrutia was born in Chihuahua, Chihuahua, México. After graduating from the Preparatoria Albert Einstein in Delicias, Chihuahua, she spent one school year as an exchange student at Jefferson City High School in Jefferson City, Missouri, where she earned her high school diploma. In the year 2000 she started her undergraduate studies at the Instituto Tecnologico y de Estudios Superiores de Monterrey (ITESM) Campus Monterrey. In the summer of 2002, Cecilia attended the "Design and creativity" course in Paris at the CREAPOLE Ecole de création et de design. In 2004, she spent one semester in Valencia, Spain where she took courses in EcoDesign and furniture design. In 2005, she earned her bachelor's degree in Industrial Design from ITESM with honors. In 2005 Cecilia worked at Moen Mexico as a Marketing Research Analyst and as Marketing and Product Coordinator in 2006. In August 2008, she was accepted at the Graduate School of Fine Arts Program at the University of Texas at Austin.

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