Sustainable Shoe Design with a Single Material

JungYun Lee
Sustainable Shoe Design with a Single Material

Thesis Proposal for the Master of Fine Arts Degree
Graduate Industrial Design
School of Design
College of Imaging Arts and Sciences
Rochester Institute of Technology
October 2007
JungYun Lee
Thesis/Dissertation Author Permission Statement

Title of thesis or dissertation: Sustainable shoes with a single material

Name of author: JungYun Lee
Degree: Master
Program: Industrial Design
College: JADU

I understand that I must submit a print copy of my thesis or dissertation to the RIT Archives, per current RIT guidelines for the completion of my degree. I hereby grant to the Rochester Institute of Technology and its agents the non-exclusive license to archive and make accessible my thesis or dissertation in whole or in part in all forms of media in perpetuity. I retain all other ownership rights to the copyright of the thesis or dissertation. I also retain the right to use in future works (such as articles or books) all or part of this thesis or dissertation.

Print Reproduction Permission Granted:

I, JungYun Lee, hereby grant permission to the Rochester Institute Technology to reproduce my print thesis or dissertation in whole or in part. Any reproduction will not be for commercial use or profit.

Signature of Author: JungYun Lee Date: __________

Print Reproduction Permission Denied:

I, __________________________, hereby deny permission to the RIT Library of the Rochester Institute of Technology to reproduce my print thesis or dissertation in whole or in part.

Signature of Author: __________________ Date: __________

Inclusion in the RIT Digital Media Library Electronic Thesis & Dissertation (ETD) Archive

I, __________________________, additionally grant to the Rochester Institute of Technology Digital Media Library (RIT DML) the non-exclusive license to archive and provide electronic access to my thesis or dissertation in whole or in part in all forms of media in perpetuity.

I understand that my work, in addition to its bibliographic record and abstract, will be available to the world-wide community of scholars and researchers through the RIT DML. I retain all other ownership rights to the copyright of the thesis or dissertation. I also retain the right to use in future works (such as articles or books) all or part of this thesis or dissertation. I am aware that the Rochester Institute of Technology does not require registration of copyright for ETDs.

I hereby certify that, if appropriate, I have obtained and attached written permission statements from the owners of each third party copyrighted matter to be included in my thesis or dissertation. I certify that the version I submitted is the same as that approved by my committee.

Signature of Author: JungYun Lee Date: __________
Sustainable Shoe Design with a Single Material

School of Design
College of Imaging Arts and Sciences
Rochester Institute of Technology
October 2007
JungYun Lee

Committee

Professor David Morgan
Chief Advisor
Rochester Institute of Technology
School of Design
4624 James Booth Building
dcmfaa@rit.edu
(585) 475 4769

Professor Alan Redding
Associate Advisor
Rochester Institute of Technology
School of Design
4624 James Booth Building
areddig1@rochester.rr.com

Professor Nancy Chwiecko
Associate Advisor
Rochester Institute of Technology
School of Design
4624 James Booth Building
nacfaa@rit.edu

Professor Patti Lachance
Administrative Chairperson
RIT School of Design
pjfaa@rit.edu
(585) 475 2667

Editor

Lori D. Dabbagh
Writing Center Instructor
Rochester Institute of Technology
Academic Support Center
2350 Eastman Building
ldnolasco@gmail.com
# Table of Contents

## Thesis Project Definition

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Problem Statement</td>
<td>4</td>
</tr>
</tbody>
</table>

## Situation Analysis

<table>
<thead>
<tr>
<th>Topic</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shoes Sold in US</td>
<td>5</td>
</tr>
<tr>
<td>Shoe Waste</td>
<td>6</td>
</tr>
<tr>
<td>Shoe Recycling</td>
<td>11</td>
</tr>
<tr>
<td>Shoe Repairing</td>
<td>14</td>
</tr>
<tr>
<td>Observation</td>
<td>16</td>
</tr>
</tbody>
</table>

## Research

<table>
<thead>
<tr>
<th>Topic</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Green Manufacturing Solutions:</td>
<td></td>
</tr>
<tr>
<td>Molding</td>
<td>17</td>
</tr>
<tr>
<td>Industrial Quality Material, Single Material</td>
<td>23</td>
</tr>
<tr>
<td>No glue, No Stitching</td>
<td>26</td>
</tr>
<tr>
<td>Other Green Solutions</td>
<td>27</td>
</tr>
<tr>
<td>Consideration for Shoe Design:</td>
<td></td>
</tr>
<tr>
<td>Standard Shoe Size</td>
<td>28</td>
</tr>
<tr>
<td>Shoe Parts</td>
<td>31</td>
</tr>
<tr>
<td>Green Market Solutions:</td>
<td></td>
</tr>
<tr>
<td>Inviting Design</td>
<td>32</td>
</tr>
<tr>
<td>Easy User-replaceable Parts System</td>
<td>33</td>
</tr>
<tr>
<td>Education</td>
<td>35</td>
</tr>
</tbody>
</table>

## Ideation Process

<table>
<thead>
<tr>
<th>Topic</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Marker Rendering and Sketch Model</td>
<td>36</td>
</tr>
</tbody>
</table>

## Final Development

<table>
<thead>
<tr>
<th>Topic</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>SolidWorks Model</td>
<td>48</td>
</tr>
<tr>
<td>3D Printing</td>
<td>49</td>
</tr>
<tr>
<td>Mold Making</td>
<td>53</td>
</tr>
<tr>
<td>Technical Drawing</td>
<td>57</td>
</tr>
</tbody>
</table>

## Application

<table>
<thead>
<tr>
<th>Topic</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Final Appearance Model</td>
<td>60</td>
</tr>
<tr>
<td>Market Response</td>
<td>63</td>
</tr>
<tr>
<td>Logo</td>
<td>64</td>
</tr>
<tr>
<td>Web Site</td>
<td>65</td>
</tr>
</tbody>
</table>

## Conclusion

<table>
<thead>
<tr>
<th>Topic</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conclusion</td>
<td>68</td>
</tr>
</tbody>
</table>

## Future Possibility

<table>
<thead>
<tr>
<th>Topic</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Future Possibility</td>
<td>69</td>
</tr>
</tbody>
</table>

## Bibliography

<table>
<thead>
<tr>
<th>Topic</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bibliography</td>
<td>70</td>
</tr>
</tbody>
</table>

## Contact

<table>
<thead>
<tr>
<th>Topic</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Contact</td>
<td>72</td>
</tr>
</tbody>
</table>
Problem Statement

People tend to throw away a shoe rather than repair it for further use. This means more and more shoes are thrown away, and since a shoe is made out of many kinds of materials¹ that are all glued or stitched together, it is difficult to recycle or reuse the shoe. Additionally, there is a symbolic relation between the land and shoe; a shoe is the product that connects people to the ground.

Symbolic meaning of a shoe

People
Shoes Connection to the earth: the first object to directly connect human to the ground
Earth(Ground)

It is ironic that a shoe, which provides the connection, has a negative effect on the land. If we wear a shoe longer, we can reduce the number of discarded shoes and have a positive effect on the environment. I want to design a sustainable shoe by making it last longer and making it recyclable with replaceable parts, so users can simply change a part when it wears out or when they want to try a different style and function. It can be made with an industrial quality material. At the end of their serviceable life, shoes can be easily recycled or reused. The shoes can be used to make other shoes and other products.

Industrial mass-production generates garbage and chemical byproducts. Byproducts of both the original manufacturing processes and the subsequent breakdown of product materials are major factors in land contamination. Chemical components and unhealthy materials both present many problems. Poor design degrades the environment, as the soil does not safely absorb these wastes.

Sustainable Shoe Design with a Single Material

**Situation Analysis**

**Shoes sold in the US**

American apparel, shoes, and accessories account for combined retail sales of approximately $450 billion annually, an amount equal to about 80% of the food and grocery sector's sales at retail.  

<US Market in 2006>

![Diagram: Food (100%) and Shoes and Accessories (80%)](image1)

-U.S. Apparel and Footwear Association-

U.S. consumers spend more than $20 billion annually on footwear, according to the Census Bureau's Statistical Abstract of the United States. About 493 million pairs of athletic shoes were sold in 2004, an increase of almost 5% from 471 million pairs sold in 2003, according to NPD Group/NPD Fashionworld.

<US Shoe selling growth>

![Diagram: Number of pairs sold (in millions)](image2)

-NPD Group/NPD Fashionworld-

---


Sustainable Shoe Design with a Single Material

Situation Analysis

Shoe Waste

Analysis of Shoe Waste

People tend to throw away a shoe rather than repairing it for longer wear. More and more shoes are thrown away, and since shoes are made from a wide variety of materials, including plastic, rubber and leather that are all glued or stitched, they are very hard to recycle or reuse.

Biological materials + Industrial Materials

Thrown out = Wasteful

Burning out = Not safe

Incinerator smoke from the typical garbage with its mixture of industrial and biological materials.6

6 Ibid., 109-115.
Situation Analysis

Shoe Waste

Two generally accepted ways to extend shoe life

Rotate Two Pairs of Shoes

It is a good idea to have two to three pairs of walking or running shoes to alternate. Rotating multiple pairs of shoes increases their longevity. Using multiple pairs of everyday shoes is better than having a single pair. In addition, switching between two pairs of shoes gives time for the mid-sole to decompress and if moist, the shoes will have time to dry. Walking shoes tend to wear out at two points: the outer heel and at the point where a walker pushes off with the big toe.7

Take Them Off Properly

Removing ones shoes gently, which includes unlacing and removing them by hand instead of pushing off the shoe with ones feet, lessens wear on the shoe.7

Situation Analysis

Shoe Waste

A Shoe’s Life Span

Most running and walking shoes last approximately five hundred miles, a distance that varies depending on how and where the shoes are used. For example, pavement wears down shoes faster than a track, a trail, or gravel. Also, shoes with an EVA midsole tend to wear down faster than shoes with a polyurethane midsole. 

Numerous factors, including the weight of the user and the training environment, affect how long most running shoes will last. Also, a lightweight pair of trainers will not generally last as long as a sturdy motion control trainer. Lighter products tend to have less durability.

Many runners keep records of their mileage to monitor when to get new trainers. Others switch every three to six months and still others wait until a nagging injury appears when their shoes are worn out and disappears when the athlete switches to a fresh pair of shoes.

Generally, one should replace a pair of walking shoes when one has walked in them approximately four hundred miles. Everybody is different. Some people strike harder or softer than others. Some walking shoes wear better than others. One can tell when it is time to replace them by noticing the wear on the bottom and sides of the shoes.

Situation Analysis

Shoe Waste

Composition of shoe

Shoes generally have multiple layers of differing materials, and the glues and stitching make the materials difficult to separate for recycling. I selected a sample of casual shoes and studied them to see how many materials and layers were used, and to see how they were bonded. Here are four examples that illustrate the materials and methods in common use.

Case A

Purpose: walking, running, playing basketball
Used materials: Polyurethane, plastic, nylon, rubber, and sponge
Attachment technique: Glue and stitch

Case B

Purpose: walking
Used materials: Leather, rubber, and fabric
Attachment technique: Glue and stitch
Situation Analysis

Shoe Waste

Composition of shoe

Case C

Purpose: walking
Used materials: Leather, plastic, fabric, and rubber
Attachment technique: Glue and stitch

Case D

Purpose: walking, running, playing tennis
Used materials: Polyurethane, plastic, foam, nylon, and rubber
Attachment technique: Glue and stitch
Situation Analysis

Shoe Recycling

Why are shoes not recycled today?

Shoe recycling simply transfers waste elsewhere. Because of the mix of materials used in a shoe, recycling the shoe causes down cycling. This creates lost value and degrades the quality of the materials, in addition to increased costs and contamination of the bio-sphere.\(^8\)

**Shoe recycle = Not popular**

Usually recycling companies does not sponsor shoe recycling.

**Shoe recycle = Too complicated**

We need a specialist to recycle a shoe.\(^9\)

www.europeanrecycling.co.uk/

**Shoe recycle = Limited**

No shoes that include metal eyelets, zippers, batteries, cleats or spikes are accepted. No flip flops, pool shoes, sandals, dress shoes, boots or slip-ons are accepted.\(^10\)

New Try

Several companies collect old shoes and grind up the rubber and fiber. The rubber can be granulated and re-used and the fiber fluff can be used for bedding, padding, or home insulation. As an example, Nike runs the Reuse-a-Shoe Program.\(^10\)

---

\(^8\) William McDonough and Michael Braungart, *Cradle to Cradle: Remaking the Way We Make Things* (New York: North Point Press, 2002), 56.


I contacted several recycling organizations to ask about the feasibility of recycling shoes and what we can do to promote shoe recycling. I couldn't get specific details, but did receive some general information.

The following is an email from the RecycleNow helpline. RecycleNow is the national recycling campaign for England.

Thank you for contacting the RecycleNow helpline.

Please note that at RecycleNow we are a general information service about domestic waste recycling. As such, we are unable to provide specific information about the technical side of shoe recycling. However, you may find the following fact sheet from WasteOnline of use:

http://www.wasteonline.org.uk/resources/InformationSheets/Textiles.htm

Please note that shoes can be recycled at most recycling centres, or donated to a charity shops. Pairs of shoes in good condition can be donated to charity shops. Charities like Oxfam, Save The Children, Barnado's, Age Concern and Cancer Research have chains of high street shops:

http://www.oxfam.org.uk/
http://www.savethechildren.org.uk/scuk/jsp/newhome.jsp?flash=true
http://www.barnardos.org.uk/
http://www.ageconcern.org.uk/
http://www.cancerresearchuk.org/
Situation Analysis

Shoe Recycling

E-mail with Recycidenow

The Variety Club also has 3000 shoe recycling sites throughout the UK, mostly found in supermarket car parks and in some specialist shoe shops, such as Up & Running:


Nike's Reuse-A-Shoe program accepts used athletic shoes in any state. They are converted into surfaces for basketball courts, tennis courts and running tracks:


We hope this is of use to you.

Please feel free to contact us again via email or telephone if you need further information.

Regards
RecycleNow
Situation Analysis

Shoe Repairing

Analysis of shoe repair

The number of shoe repair shops is decreasing. Limited types of shoes can be repaired: casual shoes and athletic shoes require a special repair service that general shoe repair shops can't provide. Even though repairing old shoes can be far cheaper than buying a new pair, people don't usually bother to repair their shoes because it's hard to access the service and the repair cost is expensive. Dress shoes and pumps are often fixed, but casual shoes, and athletic shoes are rarely fixed when they wear out, because regular shoe repair shops don't deal with those shoes, and many people don't know how they can fix them.

- Economy
  Producers make shoes in more economical ways to reduce the selling price and to maintain or increase profits. Sometimes buying a new pair of shoes is more economical than repairing an existing pair.

- Inconvenient
  Customers have to bring their shoes to the repair center, and wait to get them fixed, which can take from 1 day to 7 days. Many people don't want to bother.

- Low accessibility
  Many shoe repair shops don't provide repair service for casual and athletic shoes.
Situation Analysis

Shoe Repairing

Interviews with local shoe repair shops

"Less people come to repair their shoes compared to the 90s," said Cobblers Corner Shoe.

Cobblers Corner Shoe
(376 Jefferson Rd. 585-475-1951)

A general shoe repair shop, inexpensive. They don't usually fix casual shoes.
Price $8-15
Repair time 15-20 minutes

"We get rid of the entire outsole part from the casual shoes and replace it with another outsole, but it's not able to have the same kind of outsole. We will use different material and a different colored outsole for replacing," said Foot Performance.

Foot Performance Ctr
(3385 Brighton Henrietta Rd. 585-473-5950)

Specialize in casual shoes, and the repair of Birkenstocks.
Price $30
Repair time One week

"Back then shoes were made by more repairable ways [i.e., more easily repairable]; they had simpler layers, and used nails to combine each part. Recently, especially casual shoes have a very complicated structure and they use glue," said Sofia shoe service.

Sofia Shoe Service
(1476 Monroe Ave. 585-244-5907)

This is a general shoe repair shop which has been in business 70 years.
Price $30-35
Repair time 1 1/2 hours
Situation Analysis

Observation

People throw away their shoes when they don't want to wear them anymore. It's difficult to spend the time necessary to recycle and to make the extra effort for the environment. We need to change the consumers' awareness, although it's difficult for customers to be aware of sustainability.

I think at this moment sustainability can be achieved through better and more accessible design; the customers can be educated through a well designed product.

What if we make it easy for people to buy and keep their shoes? By using the proper manufacturing system, good design, accessible service, and simplified recycling, the entire process can be improved. Our society needs both a product and a system for the product to give customers the satisfaction of buying well-designed and responsible products that can protect the environment.

From my research, I believe sustainability can be best achieved through better design.
Sustainable Shoe Design with a Single Material

Research

Green Manufacturing Solution: Molding

Benefits of Molding

Molding is a positive solution for the environment. If a shoe is made by molding with a single material, it doesn't require disassembly or separation of parts, which makes the recycling process simpler.

- Low direct emission levels\textsuperscript{12}
- Low energy consumption\textsuperscript{12}
- Less waste of raw resource, and materials in production and application
- Easily recyclable

Domestically manufactured

Production is mostly in Third World countries.
- Third World countries where regulations are lax
- Vertically built manufacturing system

*Research on Shoes Sold in US - p.21

Sustainable Shoe Design with a Single Material

Research

Green Manufacturing Solution: Molding

Benefits of Molding

<Research on Shoes Sold in US>

Shoes Sold in the US - I expect molding might be one way to revitalize the shoe manufacturing industry in the United States. This is because molding requires only minimal labor and processing.

![US Shoe manufacturing statistics 1980 and 2006](image)

Today only 2 percent of all shoes sold in the U.S. are made domestically. In contrast, in 1980, fully one-half of all footwear in the United States was produced here. U.S. imports from China account for over 85 percent of its shoe imports. The US imported over $30 billion worth of footwear and apparel from China. (Today, fewer than 630,000 people work in the manufacture of apparel, textiles and shoes in the United States – a loss of over 1.6 million jobs, or almost three-quarters of the workforce producing those products in 1974.)

---

Green Manufacturing Solution: Molding

Injection Molding

Injection molding is the most productive process for plastic. It is a process used to produce parts from thermoplastic material. Injection molding is used for a wide range of product parts from toothpaste caps to car frames. Injection molding is particularly useful for parts with curvature and other complicated shapes.

Examples of injection-molded parts
(http://www.plasti-coat.com, Plasti-Coat Corp.)

Capacities:
28 to 250 ton, 1/3 to 20 oz.

Applicable materials:
all thermoplastic, from PVC to liquid crystal polymers\textsuperscript{14}

\textsuperscript{14}Injection Molding: Injection Molding Capabilities; http://www.plasti-coat.com/injmldg.htm (accessed March 05, 2007).
Green Manufacturing Solution: Molding

Injection Molding

Molding (Injection molding) process

- **Mold**: An injection mold is the inverted form of the product's shape. For molding process you have to make sure that your part will not be locked into the mold. Molds usually have two halves (called the core and the cavity) to have the part to be extracted after cooling.

- **Clamping**: The most common manual clamps are bolts, but molds are also clamped by magnetically or electrically for the injection process.

- **Injection**: In the injection process, heated plastic is injected into the mold at high pressure and temperature.

- **Cooling**: Mold cooling must be designed to dissipate the heat of the molding quickly and uniformly.

- **Ejection**: The method of ejection has to be adapted to the shape of the molding to prevent damage.

<Injection Molding Process>
Research

Green Manufacturing Solution: Molding

Existing Molded Shoes

Clog
(http://www.clogsonline.com/)

Mi-on
(http://www.mionfootwear.com/)

Mi-on
(http://www.mionfootwear.com/)

Sketchers
(http://skechers.com/)

EVA slipper mold
(http://kanhao.hisupplier.com/)

EVA slipper
Sustainable Shoe Design with a Single Material

Research

Green Manufacturing Solution: Molding

E-mail with Mi-on

Mi-On is an environmentally friendly shoe produced by Timberland. Mi-On uses a molding technique to form the body of the shoe with a single material; however, the company is able to produce many different textures and colors. Mi-On has the most advanced level of molding shoe in terms of the quality and execution. Since I want to use molding to produce a shoe from a single material, I contacted Mi-On to ask manufacturing questions. I obtained some information about the material and the molding method they used.

Below is an email I sent to Mi-On, and the response from Mi-On.

Hello, my name is JungYun Lee, a graduate student majoring in industrial design at RIT. I'm working on sustainable shoe design as a thesis project. I'm highly interested in Mi-On's solution and I have read about your business through the website, but I have some questions.

My questions are:
Is Mi-On made with double-injection molding method?  How does Mi-On show different textures and colors if it is made out of only one material EVA. Will the shoes be recycled or reused after consumer use? I'll very appreciate if you write me back. Thank you for your time.

Answer from Mi-on:
We utilize injection molded EVA (IMEVA). This is a single injection. There is texture built into the injection mold. We use various colors of EVA and apply films onto the sandals to achieve various colors / patterns. IMEVA is recyclable... e.g. It can be ground up to be used in other products (running tracks, sport courts etc). We are also investigating methods to use recycled IMEVA "powder" to used in new sandals.
Research

Green Manufacturing Solution: Industrial Quality material, Single Material

Industrial Quality Material

Technical Nutrient: Using a material which has been through an industrial process such as plastic.15

This shoe is made of an industrial quality material; it will make the shoe last longer. The industrial quality material allows the product to be more durable.

Durability:

Products with industrial quality materials can achieve exceptional durability and low maintenance requirements. These products are environmentally attractive because they need to be replaced less frequently and their maintenance has very low impact. Sometimes, durability is a contributing factor to the green designation.

Conservation of the natural resources

Using an industrial quality material helps conserve the environment by reducing the effort, and the associated pollution, required to harvest raw materials.

Molding possibility

Industrial quality material is used for molding. Molding is a greener way to produce a product because it can reduce pollution and waste from operations and uses less material than the standard solutions.

Research

Green Manufacturing Solution: Industrial Quality material, Single Material

Industrial Quality Material

Possible materials include plastics, polymers, polyurethane and Poliyou. These materials are less harmful to the environment and can be recycled easily.

Polyurethane is one of the best and most durable materials available to make soles on shoes. Polyurethane always holds its shape. Polyurethane adds stability and weight to the shoe. Polyurethane's density and durability offers a combination of cushioning and stability.

EVA is a lightweight, foam-based cushioning material. Inside many shoes you can find a firmer, denser piece of EVA called dual-density EVA placed in the shoe to reduce the amount of pronation (walking on the outside of the foot). The length of the post determines the amount of control.

POLIYOU® is a patented open cell Polyurethane foam developed to provide a blend of "cushioning" with a built in "moisture movement system". Poliyou® is breathable, and absorbs moisture and odor with "natural active carbon" and slows the growth of fungus and bacteria with Aegis® anti-microbials.16

Sustainable Shoe Design with a Single Material

Research

Green Manufacturing Solution: Industrial Quality material, Single Material

Single Material

Why a single material is more beneficial?

- Minimal Environmental Footprint
  A product with one material uses resources efficiently because such use can eliminate the need for extra materials. Using one material can also be positive for the environment because a simpler manufacturing process should produce less pollution.

- Easily recycled
  A product that is made out of one material makes recycling easier.

Cross sections of the single material shoe

I designed a shoe using a single material, so in every cross section view it shows a single material.

<Cross section views of the shoe model in SolidWorks>

Top cross section view  Front cross section view  Side cross section view
Sustainable Shoe Design with a Single Material

Research

Green Manufacturing Solution: No glue, No Stitching

With low or no labor cost, no adhesives, and no secondary processes used during manufacturing, less energy would be consumed. Also, the cost and the risk of exposure to toxic chemical components would be lessened.

With my design, I don't have to glue or stitch the sole to the body. This shoe doesn't need glue. The absence of glue makes recycling easier and shows a commitment to the environment and the future.

Toxic chemical components of glue and leather

Many types of glue contain a dangerous chemical component, chromium. Chromium is a heavy metal used in large-scale leather tanning processes. Cancers can be caused after long term exposure of 20 years or more to chromium17

Easy recycling

Easy to separate when it is recycled.

Green Manufacturing Solution: Other Green Solutions

Using less material:

Arrowhead

Arrowhead Water reduced the amount of plastic to make the bottle, so that they can produce less waste. The thickness of the bottle became very thin, and the length of the label is shorter.

Arrowhead Bottle
(http://www.arrowheadwater.com/)

Using a sustainable material for the environment:

Biota

Biota Water uses a corn based material for the bottle. The corn based material is reusable and not harmful when it’s thrown away.

Biota Water bottle
(http://www.biotaspringwater.com/)
Consideration for Shoe Design: Standard Shoe Size

Shoe size standards are different in various countries. There are three major shoe size standards in the world. They use different ways to measure the size of feet, and measurement units. For the international market, ISO 9407 is used. Here is the brief description of the three standards in terms of countries and the measurement units.

<table>
<thead>
<tr>
<th></th>
<th>International standard (ISO 9407)</th>
<th>European standard (EN13402)</th>
<th>United States and Canada standard</th>
</tr>
</thead>
<tbody>
<tr>
<td>Description</td>
<td>Europe, Korea, Japan use this standard, measured in millimeters.</td>
<td>This standard is also used for clothes, measured in centimeters.</td>
<td>The measurement unit is inches.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Standard</th>
<th>35.5</th>
<th>36</th>
<th>37</th>
<th>37.5</th>
<th>38</th>
<th>39</th>
<th>39.5</th>
<th>40</th>
</tr>
</thead>
<tbody>
<tr>
<td>International standard (ISO 9407)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>European standard (EN13402)</td>
<td>35</td>
<td>35.5</td>
<td>36</td>
<td>37</td>
<td>37.5</td>
<td>38</td>
<td>38.5</td>
<td>39</td>
</tr>
<tr>
<td>United state and Canada standard</td>
<td>5</td>
<td>5.5</td>
<td>6</td>
<td>6.5</td>
<td>7</td>
<td>7.5</td>
<td>8.5</td>
<td>9</td>
</tr>
</tbody>
</table>

<Table of shoe sizes in international standard, European standard, United States and Canada standard>\(^8\)

Research

Consideration for Shoe Design: Standard Shoe Size

Men and women's shoe sizes are different. Men's shoes are a little bigger than women's shoes of the same size.

![Puma's Size Chart](http://www.puma.com)

<Table of men and women's shoe sizes in U.S.>\(^\text{16}\)

<table>
<thead>
<tr>
<th>U.S. Men's</th>
<th>4</th>
<th>4.5</th>
<th>5</th>
<th>5.5</th>
<th>6</th>
<th>6.5</th>
<th>7</th>
<th>7.5</th>
<th>......</th>
</tr>
</thead>
<tbody>
<tr>
<td>U.S. Women's</td>
<td>5.5</td>
<td>6</td>
<td>6.5</td>
<td>7</td>
<td>7.5</td>
<td>8</td>
<td>8.5</td>
<td>9</td>
<td>......</td>
</tr>
</tbody>
</table>

Consideration for Shoe Design: Standard Shoe Size

The range of shoe sizes for each shoe brand is not regulated. The range of shoe sizes differs by shoe brand, and each shoe model has a different range of shoe sizes. Here is a graph showing shoe size ranges of three major shoe brands, NIKE, PUMA, and ADIDAS based on their website.
Consideration for Shoe Design: Shoe Parts

Each part of a shoe has a specific name depending on the location, function, and shape.

Online Dictionary is used for the definitions of the shoe parts.

Insole: The inner sole of a shoe or boot.20

Upper: The part of a shoe or boot above the sole.

Strap: A flexible and narrow band to tie and hold shoes.

Toe box: The forward tip of the upper of a shoe or boot that provides space and protection for the toes.

Outsole: The outer sole of a shoe.

Midsole: Cushioning between the outsole and the insole of a shoe.

Research

Green Market Solutions: Inviting Design

Usually customers don’t expect shoe manufacturers to have an improved environmental performance (except for environmentalists or a few groups of people who care for the environment enthusiastically). Most purchasers care only about price, design, and durability. So it is very crucial for a green product to meet the customer’s satisfaction expectations. It should not scream the eco friendly concept by its green-looking design. The design should be inviting and accessible to any customers.

What Buyers Say Is Important in Footwear

<table>
<thead>
<tr>
<th>Feature</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Comfort, fit and feel</td>
<td>83%</td>
</tr>
<tr>
<td>Suits active lifestyle</td>
<td>63%</td>
</tr>
<tr>
<td>Has performance advantage</td>
<td>56%</td>
</tr>
<tr>
<td>Has fashion advantages</td>
<td>54%</td>
</tr>
<tr>
<td>Meets basic needs</td>
<td>50%</td>
</tr>
<tr>
<td>Good for everyday wear</td>
<td>41%</td>
</tr>
<tr>
<td>Has conservative appearances</td>
<td>29%</td>
</tr>
<tr>
<td>Has good brand aura</td>
<td>27%</td>
</tr>
<tr>
<td>Is “hot” with friends</td>
<td>2%</td>
</tr>
</tbody>
</table>

-Athletic Footwear Association-

http://books.google.com/books?id=2MOrDkKokat8C&pg=PA324&dq=what+buyers+say+is+important+in+footwear&source=web&ots=mAREud-9Ig&sig=TgkYXg2Vxe62BP01WTmropMq0V4U (accessed October 02, 2007).
Research

Green Market Solutions: Easy User Replaceable Parts System

People mainly throw shoes away because of the worn out outsole, and the outdated styles. I thought about making each piece of shoe is replaceable, so users can simply change the certain part for the reasons of fashion or wearing longer.

I did a survey on why people throw away their shoes and used the research results to decide which parts to make replaceable. I surveyed 25 people from age 18 to 43.

<table>
<thead>
<tr>
<th>Why do you throw away your shoes?</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Worn out outsole</td>
<td>83%</td>
</tr>
<tr>
<td>Worn out material, color</td>
<td>63%</td>
</tr>
<tr>
<td>Insole</td>
<td>56%</td>
</tr>
<tr>
<td>Outdated style</td>
<td>54%</td>
</tr>
</tbody>
</table>

-Research by JungYun Lee 2007-
Green Market Solutions: Easy User Replaceable Parts System

Survey form with personal information and questions

**PERSONAL INFORMATION**
(Please fill in the personal information before the survey below)

1. Name [Please type your name] (max 25 char)
2. Your Email Address [Please type your email]
   (No blank spaces or special characters)
3. Gender
   - Male
   - Female
4. Age
   - 16-19
   - 20-22
   - 23-25
   - 26-29
   - 30-34
   - 35-39
   - 40-45
   - 46-50
5. Job
   - Please Select your job
     - Business
     - Politics
     - Environmental

**SURVEY**

1. Have you had the experience of having throw away your favorite pair of shoes?
   - Yes
   - No

2. If yes, why did you have to throw them away? What was the problem?

3. If your shoes (mostly outsole) are easily repairable and last longer, do you think you would wear the shoes a lot longer?
   - Yes
   - No

4. If your favorite shoes could be kept in good condition, how long do you expect to wear them?
   - 1 year
   - 2 years
   - 3 years
   - Longer than 4 years
Green Market Solutions: Education

If the green products are welcomed by the customers it can change the behavior of users gradually, and it will bring better environmental performance in the future. By the website and the product description we can provide information to the customers, and they can learn the green concept behind the product, and put more meaning in it. If they feel good with the whole thing, environmental responsibility can be one consideration to buy a product next time.

<Education Process>

Buy a shoe

Find a meaning behind

Consider sustainability

Note: This process can be applied to other products.
**Ideation Process**

**Marker Rendering and Sketch Models**

Methods

Marker rendering & Sketch Models

For the ideation process, I did marker rendering. It helped me visualize the ideas quickly. I also made sketch models to check the fitting and improve the design. I used a vacuum machine to form the shoe shapes to mimic the molding effect. By testing and getting feedback on the sketch models, I modified and developed the sketch models. I used color foams, and since it's flexible and easily applicable to any foam, I could achieve satisfying results on the sketch model development. It was really helpful to figure out the final appearance model.

*Sketch Model Making*

Materials: color foams from Joann.

Process:
1. Making shoe lasts: I made wooden shoe lasts for both left and right sides.
2. Adding clay on the shoe lasts to have special shape partly.
3. Setting the foam and the shoe last on the vacuum machine.
4. Raising heat and pressure on the machine.
5. Vacuuming: When it reaches enough heat and pressure, push the shoe last into the foam, and when the foam covers the shoe last and reveals the detail of the shape completely turn off the pressure.
6. Cutting and gluing foams to make the sketch model.
Sustainable Shoe Design with a Single Material

Ideation Process

Marker Rendering and Sketch Models

Dual Injection Molding

The outsole and upper part of the shoes are made out of one material. But, they show different characteristics: hardness, flexibility, and so on.
Ideation Process

Marker Rendering and Sketch Models

Dual Injection Molding

The additional piece can provide another function to the shoes.

Configurations

+ Laces

- Laces
Ideation Process

Marker Rendering and Sketch Models

Dual Injection Molding

Shoes + Laces: Basic body part and Variations of shoelace part.
Ideation Process

Marker Rendering and Sketch Models

Pocket type of outsole and the body
Ideation Process

Marker Rendering and Sketch Models

Special shaped Body part and shoelace and outsole part
Ideation Process

Marker Rendering and Sketch Models

Special shaped Body part and shoelace and outsole part
Ideation Process

Marker Rendering and Sketch Models

Strap and hook
Ideation Process

Marker Rendering and Sketch Models

Strap and hook
Ideation Process

Marker Rendering and Sketch Model

Strap and hook
Ideation Process

Marker Rendering and Sketch Model

Strap and hook
Ideation Process

Marker Rendering and Sketch Model

Strap and hook

The last sketch model:
To show realistic volume of the shoe last I carved yellow foam, and the other parts are made of thin foam.
Sustainable Shoe Design with a Single Material

Final Development

SolidWorks Model

SolidWorks is a 3D CAD program that runs on Microsoft Windows and SolidWorks offers unmatched 2D and 3D design capabilities. I modeled the shoe parts in SolidWorks, and developed a rapid prototype by 3D printing. For 3D printing I kept the part files and sent them separately to the 3D Printer, and for rendering and presentation, I made an assembly of part files.

---

Final Development

3D Printing

SolidWorks files that are saved in STL file format can be sent to a 3D printer to make a rapid prototype model.

3D printer at the manufacturing engineering lab (Department of Manufacturing and Mechanical Engineering/Packaging Science Rochester Institute of Technology 78 Lomb Memorial Drive Rochester, New York 14623-5604)

Rapid prototype printing

Rapid prototype model samples
Final Development

3D Printing

STL file format?

The STL file format is the Rapid Prototyping industry's standard data transmission file format. The STL file converts the surfaces of a solid model into triangular polygons.²³

Final Development

3D Printing

Chosen 3D Rapid Prototype Material

- **JYPSUM + Binder**
  - JYPSUM is powder based.
  - Fairly cheap
  - Easy to break
  - Rough surface
  - Able to deal with large size of 3d printing model

- **Plastic**
  - Expensive
  - Durable
  - Fine surface
  - Only for small size of the model

Due to the capacity and the cost, JYPSUM is used for the project. The prototype models were only used as patterns to make a silicone mold. The smoothness of the surface can be adjusted by the setting and the binder, and the final silicone molds have a fairly smooth surface.
Final Development

3D Printing

Email with Redeye RPM

I contacted Redeye RPM, a professional 3d printing company in Minnesota, to ask about the 3d printing process, and for suggestions on possible materials. By contacting them I could know it is possible to directly print the shoe shape with the similar material that I want to use. The final material that I want to use was EVA or polyurethane-like materials, and Redeye RPM suggested using a little soft and flexible material called Tango Gray which is similar to EVA or polyurethane. I thought 3D printing will have a very similar result to the molding, so I considered printing SolidWorks Shoe model with the suggested material. I calculated the SolidWorks model and after estimation it was decided not to use the suggested soft material due to price and time constraints. The price to try the Tango Gray material was four to ten times higher than hard materials. For the project I decided to make a hard prototype model and silicon mold, and since RIT mechanical engineering department offers 3D printing service with hard 3D printing material, the 3D printer at the school was used. The experience of 3D printing and molding process helped to explain the manufacturing process better. Even though the final prototype model was done at Redeye RPM, it was very helpful to contact the professional rapid prototype place to learn the manufacturing possibilities and materials. The following is an exchange of emails between myself and Redeye RPM:

RedEyeRPM Logo
(http://www.RedEyeRPM.com)

Hello, I'm a graduate student in industrial design major. I'm very interested in 3D printing, and have a question about it. For my thesis I'm working on sustainable shoes made by molding.
I want to know if I can use 3D printing to make the final mock up of the shoes because I think 3D printing might be the most similar solution to molding.

My questions are:
1. Can you print this shoe shape (I attached sketches and sketch model of the shoes)?
2. How much does it cost to print a pair of shoes?
3. Can I use soft and flexible material like rubber for 3D printing?
4. Can I use a SolidWorks file for 3D printing? If not what programs or files should I use?
5. How long does it take to get the 3D printing model from the day to send you a file?
I'm considering using 3D printing for my thesis, so if you answer my questions I will be very grateful. Thank you for your time.

Answer from Redeye RPM:
You can check the price by uploading your SolidWorks file in our website. There are number of materials we can use, and I recommend Tango Gray which is soft like rubber. We accepts STL file, and you can convert your SolidWorks file to STL file in SolidWorks. Once we get the file and set the machine it will take two to three days. If you have any further questions feel free to contact me. Thank you.
Final Development

Mold Making

Silicon Mold Making Process:

1. Building a clay wall meeting the parting line.
2. Making inserts and pins.
3. Building a foam board wall around the clay.
4. Pouring silicone rubber liquid into the foam board wall.
5. Making a vent and sprue.

<Clay forming for a mold>
Final Development

Mold Making

Silicon Mold Making Process:

1. Building a clay wall meeting the parting line.
2. Making inserts and pins.
3. Building a foam board wall around the clay.
4. Pouring silicone rubber liquid into the foam board wall.
5. Making a vent and sprue.

<Silicon molds for each part>
Final Development

Mold Making

Chosen Mold Making Materials

Sealer: Super sealer (Mold release Spray)
Silicone: Mold max (Two silicone rubber epoxy)
Clay: Soap free one
Polyurethane: VYTAFLEX 20 (flexible & soft)
Color pigment: SOSTRONG

<Pictures of mold making materials>

Clay
Mold release
(http://bogomip.net/blog/make-your-own-3d-settlers-of-catan/)

WOOMOO 30
(http://www.smooth-on.com)

VYTAFLEX 20
(http://www.smooth-on.com)
Final Development

Mold Making

Observation: The mold with OOMOO 30 silicon turned out very well, but the VYTAFLEX 20 Polyurethane was too soft to hold the shape. The silicone is expected to work well for the shoe mock-up.

The process from SolidWorks model to the mold making was very successfully executed except the cavity. Due to the difficulty of mold making, the final mock-up ended worse than expected, and I couldn't take a good picture of the final model. However, it was a very crucial process to make a mold actually in the whole design process to explain the manufacturing concept better, and have a more believable result.

For this project, I modeled the shoe in SolidWorks, and developed a rapid prototype by 3D printing, and made a mold by using the prototype. By going through all these processes step by step, I became more familiar with the manufacturing and could understand the relationship between design, engineering and manufacturing.
Final Development

Technical Drawing

CAD Drawing

In SolidWorks I created 2d line drawings of part and assembly files with dimensions for better understanding of size and features. The measuring unit is mm, document size is letter, and the scale is 1:3.

Assembly Drawing
Final Development

Technical Drawing

CAD Drawing

Part drawing: Inner layer

[Image of technical drawing with dimensions and notes]
Final Development

Technical Drawing

CAD Drawing

Part drawing: outsole
Final Computer Generated Model
1. Put the inner layer into the outsole.
2. Hook the inner layer into the hole of the outer.
3. Put the straps around the inner layer and outer.
4. Wear the shoes.
5. You can change the parts for different looks.
Each piece of the shoe is replaceable, so users can easily change certain parts for purposes of fashion or wearing longevity.
Application

Market Response

Interviews with shoe stores

I went to shoe stores at mall and had preliminary questions about the sustainable shoe to the employees and customers.

Questions:
1. why do you want to buy or don’t want to buy this shoe?
2. Would you consider buying an environmental friendly sustainable shoe?
3. What do you consider the most when buying a shoe?
4. After finding about the green concept of the shoe, would you like to consider buying that kind of shoe?
5. Do you have any suggestions or opinions on NEAT in aspects of design and concept?

Feedback:

People said they want buy the shoe because of the appearance and the fun system of changing parts. They said that they consider the price and the design the most when buying shoes, and they don’t really care about the green concept for buying a shoe, but think positively about it. They suggested that I make more styles for men because the current design seems for women.

Interviewed Shoe Stores
Sustainable Shoe Design with a Single Material

Application

Logo

I named the shoe “Neat” which represents the clean appearance and the interlocking system, as well as concern for the environment. For the logo I came up with the blue colored arch on the top and the gray Neat text. To match with the circle shaped holes on the shoe I chose “Century gothic” font type which has a full circle figure in the letters “a” and “e”. The century gothic font also fits the simple and playful image of Neat. Previously the arch was green for the environmentally friendly identity, but I changed the green to sky blue. The sky blue still represents nature, but doesn’t shout the green concept which is what I intend with the Neat project.

The final logo is applied for the shoe, advertisement, and the website as a symbolic mark of the concept and project.

Logo Ideation Process

---

-64-
I designed the thesis website in order to present my thesis project with more interactivity in a professional manner. By clicking the rollover links on the left side, users can explore the site.

The most crucial part in the site is to show the online demo shopping option. Viewers can choose the colors for each part for the best match, and they can decide on the quantity and the size.

- Thesis site
  (http://www.yunnylee.com/neat)

- Color Choice Option
  (http://www.yunnylee.com/neat)

- Perspective Viewer with Rotation
  (http://www.yunnylee.com/neat)
Application

Web Site

If they complete the shopping demonstration, they can click “Buy Neat,” which will show a thank you message for participating without allowing the visitor to actually purchase the shoe.

The information that viewers fill in will be emailed to the designer Yun Lee (JungYun Lee-tutujy2@hotmail.com), and they will be used for further market studies and research purposes.
Application

Web Site

You can also check the research of the project, links to the resources to understand the project in advance and more detail.

Research
(http://www.yunnylee.com/neat)

Links to the resources
(http://www.yunnylee.com/neat)
Conclusion

In this project to design a sustainable shoe, I tried to make shoes and a system for solving the environmental problems that the shoe industry is creating. My conclusions are designing shoes which are easy for people to keep, and using the proper manufacturing system, simplified recycling, and good design.

To help people maintain their shoes easily I came up with assembling methods to put the single parts of the shoes together. People simply replace the part by themselves without going to shoe repair shop, and send the shoes to the company for repairing when the parts are worn out. The easy maintenance of the shoes will actually help people keep their shoes longer. Also, use of industrial quality material for all the parts makes the life span of the shoes longer and will cause less effort and energy for the maintenance.

For the manufacturing system, molding with a single and industrial material for each part was applied. Molding can minimize the manufacturing processes so that it will reduce energy consumption and harmful elements during manufacturing. Also by molding we can minimize the use of materials and produce shoes without using synthetic glue.

To simplify recycling, each part of shoe uses a single material and each part of the shoe can be separated cleanly and they are not attached at all to the main part of the shoe so that it can be easily and effectively recycled. It can solve the problems of shoe recycling which usually leads to down cycling and is harmful to both the economy and the environment. Also the single material parts are safe to throw it away.

For the design of the shoes, sporty and organic lines and playful colors were used. The interlocking assembling system of the shoes allows people to have the freedom of choosing a favorite color match for the parts. Usually green shoes have a too natural appearance and don't follow the market trend. As a result, sustainable concepts shoes are often ignored by customers because of their unappealing appearance. So I focused on designing shoes which are not green looking, but pleasant and practical looking which can actually attract customers for purchase.

The sustainable shoe design was named “Neat,” meaning the simplicity of the design and the interlocking system. The name also refers to the way the shoe will help keep a clean environment. Neat is a shoe that is made of interlocking components of a single material. This design allows for easy repairing and upgrading. The system employs a sustained production model, though the product is not marketed as such. The user is drawn to the product system by the shoes’ simplicity, customizability, and inviting design. After purchasing the initial pair of shoes, returning customers utilize an online interface to upgrade and customize their current pair or future shoe purchases. The customizable features extend the lifetime and wearability of the shoes, and thus reveal the product’s sustainable nature. The product system strives to inspire the user to consider the sustainability of future product purchases, shoe or otherwise.
Future Possibility

Different materials can be used for each part, but a single material for one part. To connect each part no glue and permanent attachment and connector are used so that the shoes or their parts can be disassembled perfectly and easily. Different material streams can be used for the inner layer and the outsole. For instance the sole part can be polyurethane, and the inner layer can be a fabric. It can be more comfortable and satisfying for people who want to touch a natural texture on the feet. Also, using a fabric for the inner layer can increase the breathability of the shoe, and the industrial stream outsole part is durable and lasts much longer. Each part can be collected separately at the end of the shoe's use and then recycled and reused. Thanks to sustainable joints each part may be detached simply and cleanly. The easy disassembly won't cause any down cycle and damage the quality of the material.
Bibliography


Bibliography


Note: Most of images are created by JungYun Lee, and those images taken from online have the address of the website under the images.
Sustainable Shoe Design with a Single Material

Contact

JungYun Lee

Phone: (585) 469 6048

E-Mail: jxl8161@rit.edu

Website: http://www.yunnylee.com