harvesting and processing requirements (Fig. 4).

- Not all environmentally preferred materials, such as water-based adhesives require an additional monetary expenditure.

The **largest sources of cost savings** include:

- Replacement of poly suede/ leather with organic cotton.
- Switching to water-based adhesives.
- Displacing the use of primary rubber with re-treaded car tire rubber.

End-of-Life Evaluation

Table 2. Evaluation of EoL **Options** (Source: GaBi 4.0)

Composting	GHG emissions (kg CO2 eq.) per pair		
	Additional	Avoided	Net
Landfilling	0.27	0	0.27
Reuse	0.17	0	0.17
Recycling	2.83	1.89	0.94
Grinding	0.04	1.52	**-1.48**
Composting	0	0.27	**-0.27**
End-of-Life Option	**Feasibility**		
	Supply Chain Steps	**Shipping distance (km)**	**Take Back Program?**
Landfilling	0	0	**no**
Reuse	1	400	yes
Recycling	2	16000	yes
Grinding	1	1500	yes
Composting	0	0	**no**

The current EoL practice for shoes--landfilling--emits GHGs (mainly methane) during anaerobic decomposition of organic matter in landfills. Reuse would emit GHGs during transportation to the secondary user. Recycling would emit GHGs during transportation, disassembly, and reprocessing, but would save GHG emissions by avoiding landfill and primary production of footwear materials. Grinding would emit GHGs during transportation, but would save GHGs by avoiding landfill and primary production of surfacing materials. Composting, done by customers at home, would result in no emissions and would save GHG emissions by avoiding landfill (Table 2).

Conclusions

The LCA results suggest that the Green Toe shoes and ecoSNEAKS do have a lower environmental impact than the conventional shoe and that the Green materials initially chosen by Simple Shoes are the reason for this superior environmental performance.

"Yes, a Green Toe shoe is simply better in terms of environmental performance than their other footwear products!!"

The supply chain analysis identified three points within the Simple Shoes supply chain that exhibited both high environmental impacts and for which Simple Shoes had at least a moderate amount of control:

- **Material composition of the shoes**
- **Manufacturing processes**
- **End-of-Life management**

Composting would be the best EoL management option for Simple Shoes because it has a negative contribution to GWP and is the most feasible alternative to landfilling.

Key Recommendations

- Simple Shoes should remove leather, synthetic materials, plastics and hybrids from their products.
- Simple Shoes should pursue energy and efficiency improvements at their manufacturing facilities.
- Simple Shoes should redesign their shoes to be 100% biodegradable so that customers can compost the shoes rather than landfill the product.

References

Staikos, Theodoros, et al. "End-of-life management of shoes and the role of biodegradable materials," Loughborough University, UK, (2006).

Cloud Institute for sustainability education "Natural or synthetic," Sustainability-ed.org, (2005).

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Analyzing the Environmental Impacts of Simple Shoes

A Life Cycle Assessment of the Supply Chain and Evaluation of End-of-Life Management Options

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Overview

- Production and consumption of footwear generates adverse environmental impacts
- Analysis of the environmental performance of shoes via a Life Cycle Assessment, Supply Chain Analysis and End-of-Life Evaluation
- Results indicate that Simple Shoes should eliminate leather and synthetics, focus efforts on materials production and compost used shoes

Introduction

Although footwear is not typically considered a commodity or industry that is particularly harmful to the environment, the sheer volume of shoes consumed each year generates significant environmental impacts. In 2004, 12 billion pairs of shoes were produced worldwide (Staikos, 2006). Traditional footwear uses both natural and synthetic materials. The production of petroleum-based synthetic materials is energy-intensive and involves the use of toxic substances; however the environmental performance of some natural materials is not considerably better.

For example, the production of 1kg of conventional cotton requires 26,100 liters of water, 16 grams of pesticides, 457 grams of fertilizers and 100 MJ of energy, and leather tanning releases chromium and other harmful chemicals (Cloud Institute, 2005). In addition to production impacts, many footwear companies have worldwide supply chains in which products are transported across the globe, burning fossil fuels that contribute to global warming.

Background Information

Simple Shoes began making shoes in 1991 and in 2005 set out to reduce their environmental impact by introducing a line of shoes made of Green materials.

This line of shoes is called Green Toe and features natural materials such as hemp, jute, organic cotton, bamboo, natural latex and crepe rubber, as well as recycled PET and recycled car tires. Thus far, the Green Toe line has been commercially successful and Simple Shoes is considering expanding the use of Green materials into their entire product line.

Problem Statement

Given the success of the Green Toe line, Simple Shoes sought to systematically analyze the overall environmental impacts of their Green material choices.

"Is a Green Toe shoe simply better in terms of environmental performance than their other footwear products?"

Further, Simple Shoes sought to find additional methods and strategies to improve environmental performance along their supply chain and to assess the incorporation of End-of-Life management.

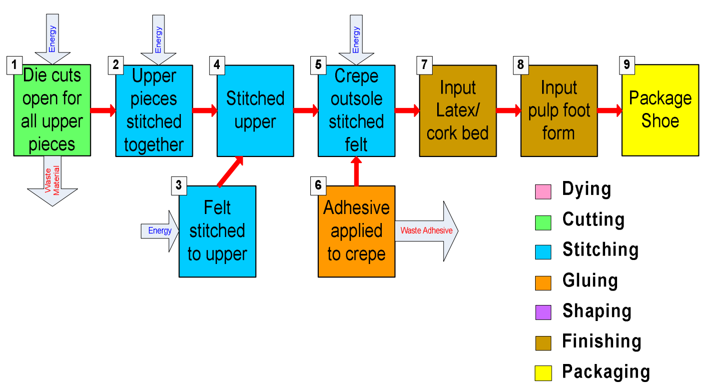
Project Objectives

- Quantify and compare the environmental impacts of four shoes, two from the Green Toe line, one from the ecoSNEAKS collection, and one conventional Simple shoe.
- Analyze Simple Shoe's existing supply chain using Life Cycle Assessment to identify opportunities for improvement in environmental performance and efficiency.
- Evaluate End-of-Life Management options based on feasibility and environmental performance.
- Recommend actions for Simple Shoes to further enhance their environmental performance.

Approach

Data collection included discussions with our client to gather information related to material composition and weight, manufacturing processes (Fig. 1), costs and energy information and distribution networks.

Figure 1. Simple Shoes, Inc. Footwear Assembly Flowchart (Shoe 1)



A **Life Cycle Assessment** quantitatively measures the total environmental impacts of four of Simple Shoes' products. The two Green Toe and one ecoSNEAK shoes (Shoe 1, Shoe 2, and Shoe 3) are composed primarily of Green materials, while the conventional shoe (Shoe 4) is made almost entirely of leather and synthetics.

We calculated the environmental impacts of each pair using GaBi 4.0 LCA software, created by PE International. The LCA measured the impacts from materials production, shoe manufacturing, transportation and disposal. This allowed us to determine which shoe has the highest impact and in what life cycle phases the majority of the impacts occur.

The GaBi software calculates the emissions from a product's lifecycle and classifies these emissions into contributions to environmental problems called impact categories. We considered ten impact categories based on their acceptance in the LCA community and the interests of our client. The emissions to each impact category are normalized to total world emissions to enable comparisons across the categories.

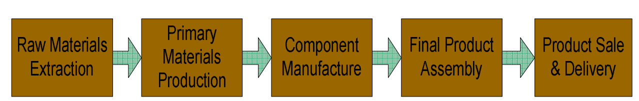
Ten Environmental Impact Categories

- Global Warming Potential (GWP)
- Human Toxicity Potentials HTP
- Marine Toxicity Potentials (MAETP)
- Terrestrial Toxicity Potentials (TETP)
- Freshwater (FAETP)
- Photochemical Ozone Create Potential (POCP)
- Ozone Depletion Potential (ODP)
- Acidification Potential (AP)
- Eutrophication Potential (EP)
- Radioactive Radiation (RAD)

The **Supply Chain Analysis** was performed to determine where Simple Shoes could modify its operations and decrease its environmental impacts. The assessment of Simple Shoes' supply chain first involved learning about the stages and suppliers currently involved in the production of their shoes, as well as the distribution channels.

We compared the supply chain of Shoe 4 (Fig. 2) to that of the Green Toe line to qualitatively and quantitatively assess the environmental and economic trade-offs.

Figure 2. Existing Supply Chain (Shoe 4)



Our **End-of-Life Evaluation** was conducted through literature review and discussions with Simple Shoes. We identified five End-of-Life (EoL) management options and two collection mechanisms: drop-off boxes and mail-in.

- **Landfilling** – Current disposal of EoL shoes
- **Reuse** – Donation to charity
- **Recycling** – Disassembly and material reprocessing for use in new shoes
- **Grinding** – EoL shoes sent to Nike's Reuse-a Shoe program to be ground up and used in athletic surfaces
- **Composting** – Customers throw EoL shoes in their home compost pile

We assessed these options and mechanisms based on their greenhouse gas (GHG) emissions and feasibility. GHG emissions were calculated using GaBi 4.0 and feasibility was determined by the additional supply chain steps and shipping distances Simple Shoes would be responsible for, as well the requirements of a take-back program.

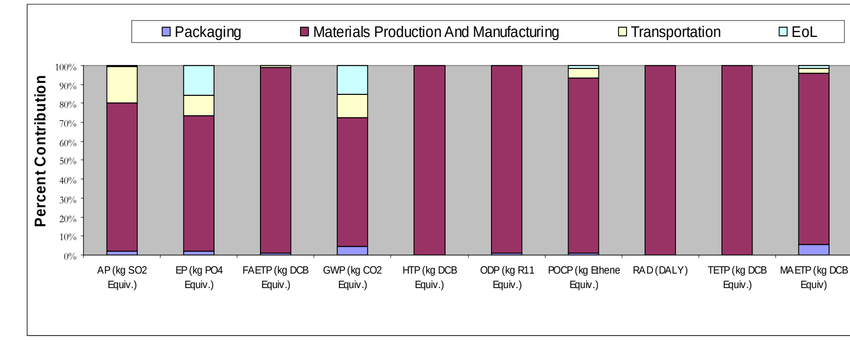


Figure 3. Relative Contribution of System Processes Across Environmental Impact Categories, Actual Data – Shoe 1 (Source: GaBi 4.0)

Results & Discussion

Life Cycle Assessment

The following table represents the LCA results for all four shoes

Table 1. Comparison of shoe styles across impact categories

Shoe Styles	AP [kg SO2-Equiv.]	EP [kg P-Equiv]	FAETP [kg DCB-Equiv.]	GWP [kg CO2-Equiv.]	HTP [kg DCB-Equiv.]
1	0.0171	0.0033	0.0402	1.672	8.482
2	0.0143	0.0028	0.0338	1.681	7.189
3	0.0092	0.0015	0.0414	1.808	10.469
4	0.0695	0.0179	0.1623	7.51	41.03

Shoe Styles	ODP [kg R11-Equiv.]	POCP [kg Ethene-Equiv.]	RAD [DALY]	TEPT [kg DCB-Equiv.]	MAETP [kg DCB-Equiv.]
1	1.48E-06	3.99E-03	1.40E-08	39.42	140.25
2	1.15E-06	2.81E-03	1.41E-08	33.35	131.28
3	7.10E-07	1.12E-03	1.54E-08	48.51	266.61
4	7.59E-07	1.68E-03	1.95E-08	190.96	796.12

(Source: GaBi 4.0)

- Greatest contribution of emissions is to toxicity impact categories, followed by Radioactive Radiation.
- Shoe 4 performs worse in 8 of the 10 environmental impact categories and Shoe 1 performs consistently better.
- Global Warming Potential (GWP) is the 6th most significant impact category of all four shoes.
- Material impact comparison revealed that leather has a GWP 5x greater than any of the other materials used.

The results of figure 3 indicate that nearly **90% of the environmental impacts occur in the materials production and manufacturing phase**. The next most impactful phases are transportation and EoL.

Supply Chain Analysis

With the use of a matrix to co-evaluate supply chain control and level of environmental payoff we determined:

- Highest environmental impacts occur during the extraction and production phases of the materials, yet the only real control Simple has over these processes is in the quality of the finished material they purchase.
- Matrix also demonstrated that EoL management options have moderate environmental impact, yet currently Simple Shoes, has little control over these options.

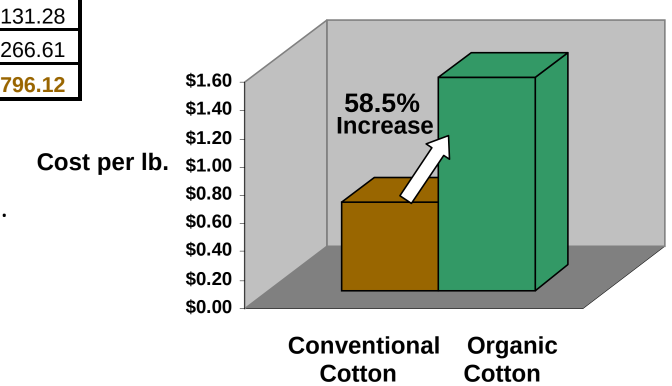


Fig. 4 Comparison of Cotton Textile Fabric Options

The supply chain analysis also included an evaluation of material costs

- Price differential between the 4 shoes studied is primarily attributed to the materials used.
- Green materials, such as organic cotton are often more expensive than their traditional counterparts due to