Water, energy and carbon footprints of a pair of leather shoes

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ABSTRACT

The shoe market is very big and complex. It is not easy for the consumer to know or estimate the true value of a product´s features and the environmental impact it has. The aim of this study is to analyze and improve a pair of leather shoes, including materials selection and end of life strategies to lower environmental pressure due to water and energy use and CO2 equivalent emissions.

The present study was divided into two main stages:

In the first stage a literature survey on the footwear industry was conducted, including the current state of the footwear industry and the current trends in footwear eco-labelling.

In the second stage, Life Cycle based footprints for carbon dioxide equivalents; water and energy were calculated and related to a functional unit. This unit was based on one pair of reference leather shoe, manufactured by Aretina Company in León, Guanajuato, México.

The footprints were calculated following the framework of Life Cycle Assessment (LCA) prescribed by ISO 14040 (ISO, 2006). The footprints analysis was performed by aid of the SimaPro software and included Life Cycle Inventories (LCIs) of water, energy and CO_2 equivalents. The analysis showed that three important potential areas for eco-shoe development are the shoe sole, the inside textile and the paper packages.

Keywords: footwear; footprints, eco-shoes, eco-design, Life Cycle Assessment (LCA), Life Cycle Thinking (LCT), Life Cycle Inventory (LCI)

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Thanks to all the persons who supported me, worked, helped, believed in me and in this project, with the joint aim of having a better world with more balance, in our natural resources and in our environment, for all living things that inhabit it.

I learned a lot from each one of you, thanks for your patience and knowledge; especially for being a family in this beautiful country.

You will always be remembered,

Thanks to readers, hope this thesis will be of interest and utility for you.

Zayetzi Rivera Muñoz.

LIST OF ABBREVATIONS

AC	Aretina Company
DTIE	Division of Technology, Industry and Economics
InWEnt	Capacity Building International
LCA	Life Cycle Assessment
LCI	Life Cycle Inventory
LCT	Life Cycle Thinking
PVC	Polyvinyl Chloride
UNEP	United Nations Environment Programme
VOCs	Volatile organic compounds

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1. INTRODUCTION

The actual manufacturing of footwear is concentrated to manufacturers based in emerging economies. Most of the emissions are released during shoes material processing 29% and during the manufacturing phase 68% (Cheah et al., 2012)

Shoe manufacture is a global industry while trade volume in it, currently increasing faster than population growth. The actual manufacturing of footwear is concentrated to manufacturers based in emerging economies. Therefore, it is highly sensitive to changes in international competitiveness and relocation strategies of major transnational companies. .In an overall perspective this may be seen as positive, because the distribution of employment in any part of the world is affected by rapid changes in production and international trade (Hernández, 2009). Shoe manufacture has important environmental impacts throughout the chain of production, distribution, consumption, waste of materials and generation of waste and garbage at the shoe end-of-life, not having a reuse or recycling system for this is a problem. It is in this sense appropriate to call the shoe industry a global pivot employment.

Since the shoe industry, together with the leather industry and the textile industry, is now one of the most globalized, it is also one of the most competitive internationally. Particularly in the last decade, the competition has intensified significantly, with increasingly competitive products and with a high quality. This has happened to the extent that its effects are not only felt in major export markets, but also among competitors, in the local markets. It is an almost paradigmatic example of hyper-global competition in the local market. For this reason, the awareness and study of ecological footwear have lacked behind globally and have had a low, impact on the ecological performance. In the case of leather shoes, the control and reduction of chromium and ammonia have been considered important steps to improve the environmental performance.(Rivela et al., 2004)

One of the primary reasons to a considerable environmental impact is that most modern footwear products contain a complex mixture of leather, rubber, textile, polymers and metallic materials. This makes it difficult to perform complete separation and reclamation of material streams in an economically sustainable manner.

Table 1 shows that China has the highest footwear consumption in the world, United States is the highest per capita shoe consumer with 6.9 pairs per year and at the other extreme, in less developed countries the per capita figure is 0.6 for India and 0.5 for Vietnam (which means one pair for each person every two years).

Table 1 Breakdown of Global Footwear Consumption (Rahimifard et al., 2007)

Countries	Population (million inhabitants)	Footwear Consumption (1,000 pairs)	Footwear Consumption /Capita/Year
EU-25	463.5	2,355,667	5.0
Germany	82.5	320,800	3.9
France	59.6	335,500	5.6
UK	59,3	312,800	5.3
Italy	57.3	395,300	6.8
Spain	41.5	136,200	3.3
Netherlands	16.1	74,100	4.6
USA	289	2,007,899	6.9
China	1,287,1	2,900,000	2.2
Brazil	186,0	490,000	2.6
India	1,041,9	N/A	0.6
Vietnam	84,2	N/A	0.5

For products environmental properties are usually communicated through eco-labels. These eco-labels have to be credible for the consumers, so they can understand and compare. In other similar aspects the eco-design therefore should be promoted through clear and reliable information, communicating its attributes that are environmentally friendly. Integrated product materials selection (IPMS) model have to be limited to the material as a physical entity to give shape to a product (Ljungberg and Edwards, 2003). The Eco-label system, based on prescription of ad hoc regulation of the European Community, represents a relevant point on action plan for environmental defence launched by the European community itself. A large part of people in Europe and over the world has reach conscience on fact that natural resources and the environment are goods really precious which have to be preserved, in order to achieve sustainable development, able to maintain the state of environment. To reach this target everybody must assume more sense of responsibility on style of life and moreover find innovative manner to improve the quality of the environment taking into account the possibility promoting at the same time economic growth.

Eco-labels are market-based instruments that are actually gaining more support at the policy level and are becoming increasingly more attractive for businesses. Enabling Developing Countries to Seize Eco-label Opportunities is a project being implemented by United Nations Environment Programme (UNEP), Capacity Building International (InWEnt) and other partner organizations. The UNEP division involved is The Sustainable Consumption and Production Branch of the Division of Technology, Industry and Economics (UNEP/DTIE).

The overall objective of the project of eco-label is to increase the environmental efficiency of key export products and related industrial processes in target countries. More specifically, it aims at increasing the number of products from target countries eco-labelled with the EU Eco-label, in domestic, European and global markets. In this case the footprint Ecolabel can be an option to be used for any shoe company around the world. The product groups identified by local partners are textiles (India and South Africa), footwear (México and Kenya), paper (Brazil) and televisions (China). Moreover, the project aims at developing a roadmap in the direction of mutual recognition between eco-labelling schemes and increasing the cooperation among developed and developing countries. This should contribute to increasing reliability of eco-labels as a marketing instrument and support efforts towards the simplification of the 'eco-labelling universe', which will eventually benefit both producers and consumers. (United Nations Environment Programme, 2009).

To date, many studies have been focused on analysing the effects that toxic-chemical substances have upon both living beings and environment. Nonetheless, this master thesis focuses on carbon, water and energy footprints, since their importance as indicator to orientate purchase choices of consumers towards environmental preferable products.

Footprints have fundamental importance for the future due to strict restrictions (scarcity of) on the use of resources such as water and energy depletion, emissions and the consumption of all natural resources. As a restriction, this master thesis, does not investigate economic and social impacts, both of which are deemed very important in relation to this industry. A more comprehensive study of footwear impact would include those factors.(Cheah et al., 2012)

In this study, Life Cycle Thinking (LCT) was applied to analyse all the stages of the footwear life cycle, for the extraction of raw materials, processing, production, use and end-of-life. A Life Cycle Assessment of the footwear was starred to identify hotspots for environmental improvements. LCA serves for the purpose of identifying potential environmental impacts and hot-spots for comparisons among different alternatives. (Tillman, 2000)

LCA is compiled of several interrelated components: goal definition and scope, inventory analysis, impact assessment, and improvement assessment.(Finkbeiner et al., 2006). The life cycle inventory serves for the purpose of calculating environmental loads (resource use and pollutant emissions) of the system in relation of the function unit.

Using life cycle assessment methodology in accordance to ISO 14040/14044 standards, this effort quantifies the life cycle greenhouse gas emissions, often referred to as a carbon footprint.(Cheah et al., 2012).This tool of LCA allow more knowledge of the product to the enterprise and can help to guide the environmental policies, are strongly recommended (Milà et al., 1998) to influence the natural environment.(Ljungberg and Edwards, 2003).

SimaPro was the software used to develop the Life Cycle Inventory (LCI) for the materials and estimate the environmental impact. This identified the impacts in the different footprints: carbon dioxide equivalents, water and energy.

After this study results, it is important to take a look in the eco-design of a new prototype of shoe, to know what are the environmental aspects, constitution materials, product specifications and evaluate their impacts. There are some footwear materials that can be recycled at the end of life, but others are not designed to be recycled. (Braungart et al., 2007)

If a shoe is designed using eco-design and produced by ecological materials, it can reduce the damage to the environment and create consumer awareness, can be introducing it, in a specific market (Ljungberg and Edwards, 2003).

Making progress in the selection of optimum materials, manufacturing processes (Ljungberg and Edwards, 2003) and identifying possible strategies to recycling the waste of this ecological shoe in the end of life cycle.

1.1 AIM AND OBJECTIVES

The aim of this study is to Analyze and improve a pair of leather shoes manufactured in Aretina Company, including materials selection and end of life strategies to lower environmental pressure due to water and energy use and CO2 equivalent emissions.

In order to achieve the aim, the following objectives are set:

- Investigate what is currently happening during life cycle of the footwear (materials used, manufacturing process, shoe lifetime, end-of-life).
- Carry out life cycle inventory based footprints for water, carbon equivalent and energy.
- Investigate types of ecological materials, to produce an eco-shoe.

1.2 DELIMITATIONS OF THE STUDY

This master thesis project focuses on the materials to produce a leather shoe manufactures by Aretina Company México. It just includes LCA based footprints of: water, energy and carbon dioxide equivalents and the analyses end-of-life strategies for ecological footwear manufacture. The system boundary of the footprint study is defined to be for cradle to downstream gate. This can be seen in Figure 1.

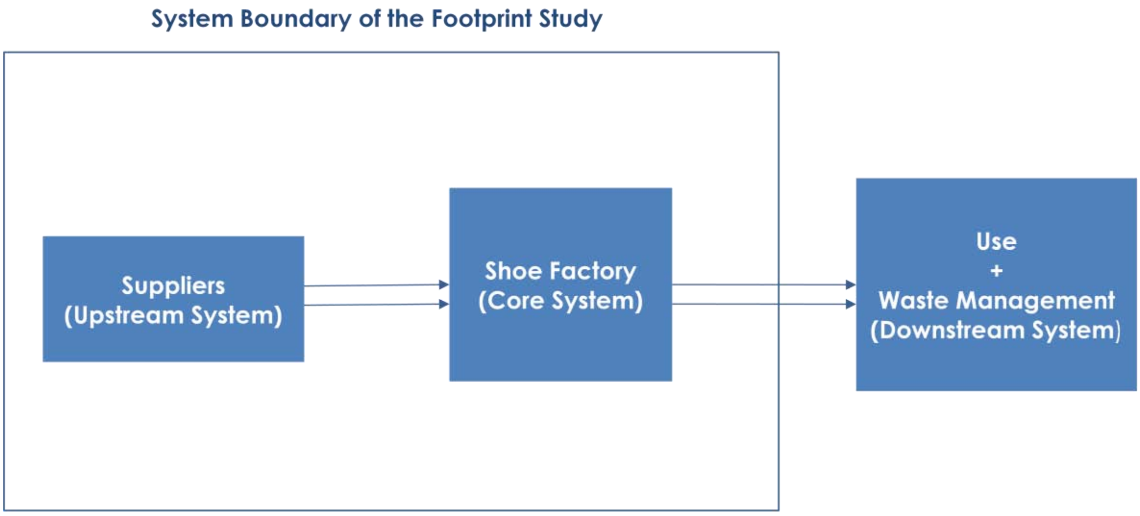

Figure 1 System Boundary of the footprint study

2. RESEARCH METHODOLOGY

This research was divided into two main stages. In the first stage, a literature survey on the footwear industry was conducted. The survey includes current state of the footwear industry and trends on footwear eco-labelling. The results of the survey are presented in Section 3 of this thesis.

In the second stage of the research, Life Cycle based footprints on Carbon, Water and Energy were performed for a selected leather shoe. The footprints were carried out following the framework of Life Cycle Assessment (LCA) prescribed by ISO 14040 (ISO, 2006). The LCA framework and the phases of the footprint study in relation to it are described in Figure 2

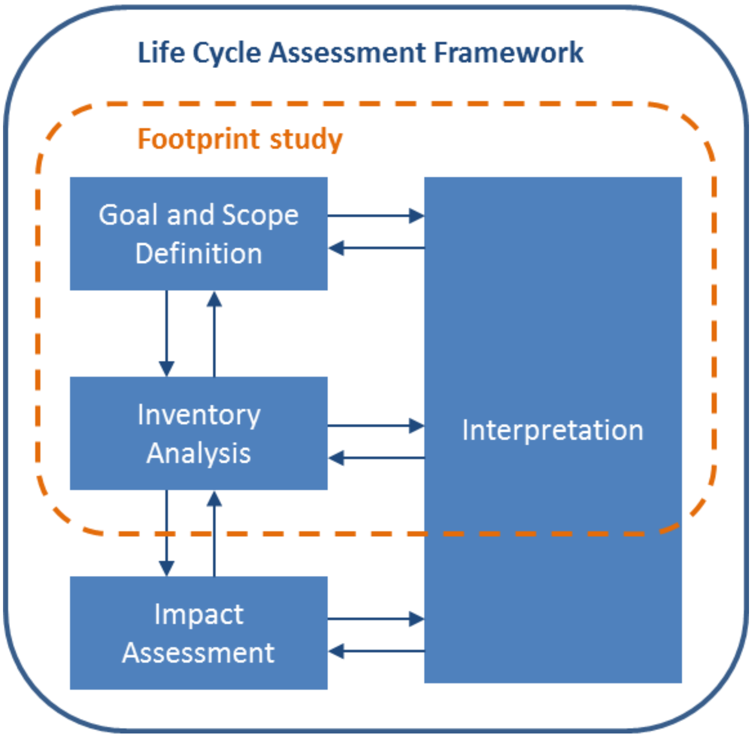

Figure 2 LAC framework and phases of the footprint study

2.1 GOAL AND SCOPE DEFINITION

The goal of the Footprint study is to perform in a life cycle perspective carbon, water and energy footprints for a reference shoe manufactured by Aretina Company (AC). The reference shoe was selected according to the following criteria:

- Style that uses low minutes of time in their manufacture.
- The design has a good utilization of cutting materials.
- It has been well accepted in the market.
- Have few parts to manufacture.
- Similar style to European designs.
- Materials common processes (without caring the environment impact).

A photo of the selected shoe can be seen bellow in figure 3.

Figure 3 Reference pair of shoes produced by Aretina Company

The functional unit of the footprint study is one pair of shoes, with a life time of 3650 hours (i.e. daily use of 10 hours per day for one year). The system boundary of the study was cradle to downstream gate. It means that the study considered the processes related to material extraction, production of the shoe parts (suppliers), and shoe manufacturing.

Emissions from the production of the energy used for manufacturing the shoe were not. For the remaining processes and materials, energy and water use, and greenhouse gas emissions – carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) – were accounted. Figure 4 shows the conceptual model of the footprint study.

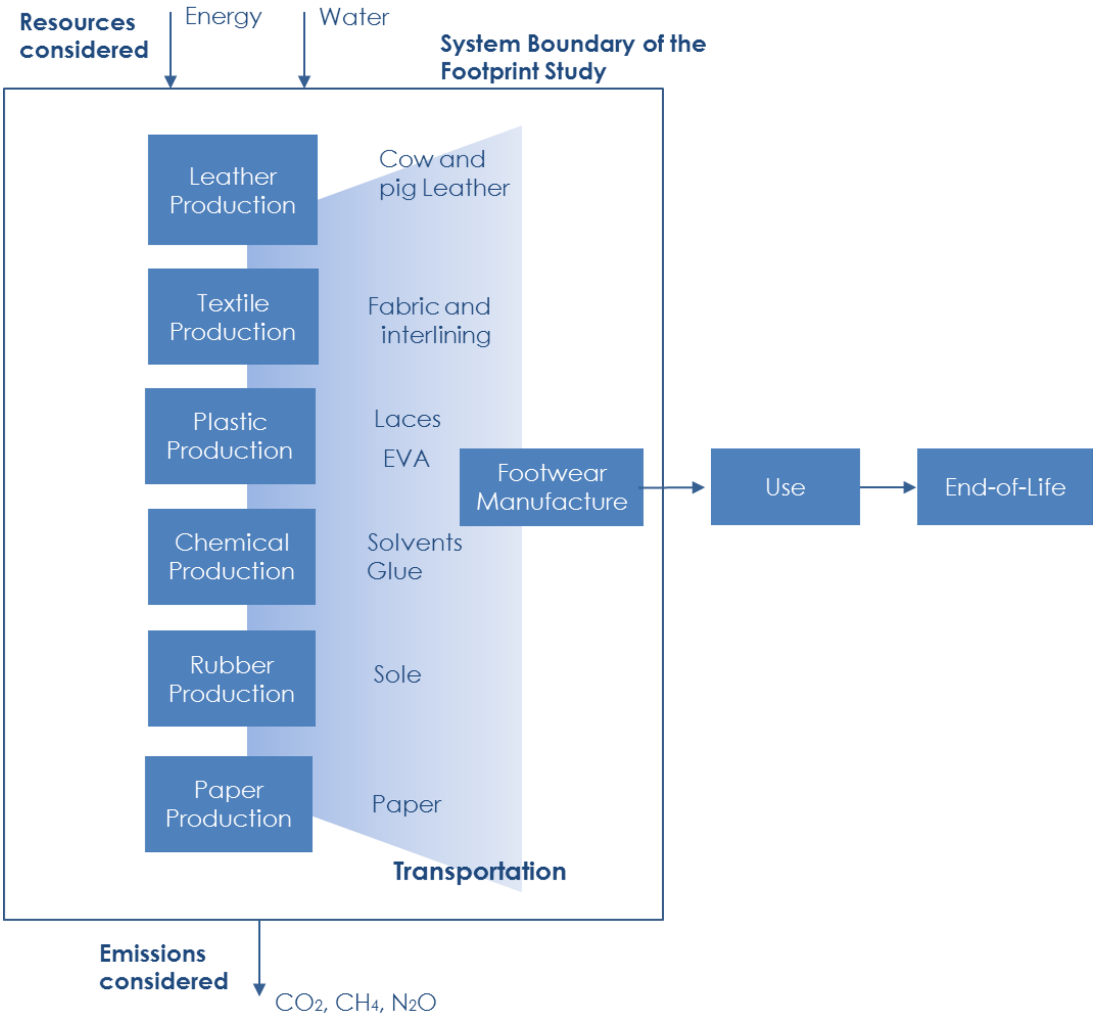

Figure 4 Conceptual model of the footprint study

2.2 INVENTORY ANALYSIS

The Life Cycle Inventory (LCI) was obtained from the database of the SimaPro software. The exceptions were (1) 'pig leather' which was obtained from (Dalgaard et al. (2007a) and the 'footwear manufacturing' which was provide by Aretina Company. Table 2 shows the inventory used in the footprint study.

Table 2 Inventory of the footprint study

Processes	Materials (1Kg)	Footprints for one Kg of materials				
		Resource use		Emissions		
		Energy (MJ)	Water (L)	CO2 (Kg)	CH4 (Kg)	N2O (Kg)
Textile production	Fabric and interlining	38.15202	59.64086	22.28644	0.12472	0.00609
Plastic production	EVA	0.91011	3.51116	1.81552	0.01199	1.92E-05
	Laces	5.89354	32.78203	5.46984	0.00808	1.43E-04
Cow leather production	Cow leather	1.29956	8.44350	0.12280	9.28E-08	2.58E-06
Pig leather production	Pig leather	0.00064	n.d.	0.00512	0.00031	3.51E-05
Chemicals production	Glue	n.d.	n.d.	0.78360	5.21E-05	2.22E-05
	Solvents	0.48776	1.66894	1.87301	0.01292	3.11E-04
Rubber production	Sole	2.03828	6.63273	2.45643	0.00750	1.18E-04
Paper production	Paper	44.99664	6.17530	2.85803	0.00172	9.38E-05
Transport 1 Km (incl. Fuel cons.)		1.80E-06	1.01E-05	5.07E-05	5.28E-08	2.52E-09
Total		**93.77854**	**118.85452**	**37.67085**	**0.16730**	**0.00683**

* n.d. = no data

* E = exponent

Table 2 shows the different reference processes and their raw materials. The data shown is for one kilogram of each material.

The calculations of the footprints were done in Microsoft Excel.

2.3 ARETINA COMPANY DATA

The next table indicates the Aretina Company (AC) data collection. In Table 1 the material quantities per pair of shoe are defined.

Table 3 Materials description of the reference shoe

Reference Shoe	
Footwear Manufacturing	**Quantity (per pair)**
Materials	**Mass (g)**
Cow leather	140
Pork leather and template	93
Fabric and interlining (textile)	42
Eva	25
Glue	168
Solvent	51
Soul	370
Lace	12
Paper	270
Water per pair	36
Energy per pair	3.24 MJ

3. CURRENT SITUATION OF THE FOOTWEAR INDUSTRY

Consumer trends in Europe reveal new attitudes on the environment as a result of widespread social phenomena in improving the quality of life, education, leisure, free time, enhanced consumption of different segments of society and reducing the number of family members. There is a marked increase in acquiring technology, and the pursuit of personalized products and unique designs based on particular preferences. Against this changing consumer, which increases their knowledge of environmental issues, is that companies should be improving the quality and increasing the value added to their products. The importance of considering the environmental benefits of a product can be demonstrated through the results of the measuring consumer behaviour in the European Union. (Eurobarometer, 2008).

The role of civil society to move towards sustainable consumption and production could be seen as crucial to reduce the environmental impacts. Increased raw material costs, producer-responsibility issues and forthcoming environmental legislations are expected to challenge the way the footwear industry deals with its end-of-life (EoL) products. It is argued that in many situations, material recycling is seen as the most suitable means of dealing with discarded shoes (Staikos and Rahimifard, 2007b). For long-term sustainability of such footwear recovery activities an economically viable material recycling system must be established (Lee and Rahimifard, 2012).

3.1 FOOTWEAR INDUSTRY

The footwear industry is undeniably global in extent. In this industry production activity is interconnected globally, through various arrangements and strategic decisions, aimed at serving the international market. The impact of the footwear industry represents a significant portion of the apparel sector´s environmental burden.

The worldwide per capita consumption of footwear has increased considerably, from 1 pair of shoes per year for every person in the world in 1950 to almost 2.6 pairs of shoes in 2005. In the EU, it is estimated that the amount of waste arising from postconsumer shoes could reach 1.2 million tons per year.(Lee and Rahimifard, 2012)

The growth of the environmental sensitivity of consumers or at least the potential importance of this niche market to purchase some products was another reason for this thesis research, as it influences the implementation of eco-design innovation through to the shoe companies.

In turn, the behaviour of environmental trends consumer buying lends support to the marketing of environmentally friendly products, in this case the footwear. Knowing the market means knowing our customers and knows how much they appreciate our efforts in environmental matters. Environmental perception documents are increasingly hopeful and human impact on the environment is increasingly devastating. Therefore, studying consumer behaviour helps companies focus their efforts on the design as a competitive advantage favourable to the environment, getting more and more consumers are concerned about the environment, though not directly related to their purchasing behaviour, which requires an analysis that escapes this document.

To start the process of relationship between products and consumers, we need to know first, the impact caused during the entire life cycle in the product acquired.

3.2 DESCRIPTION OF THE MANUFACTURE PROCESS

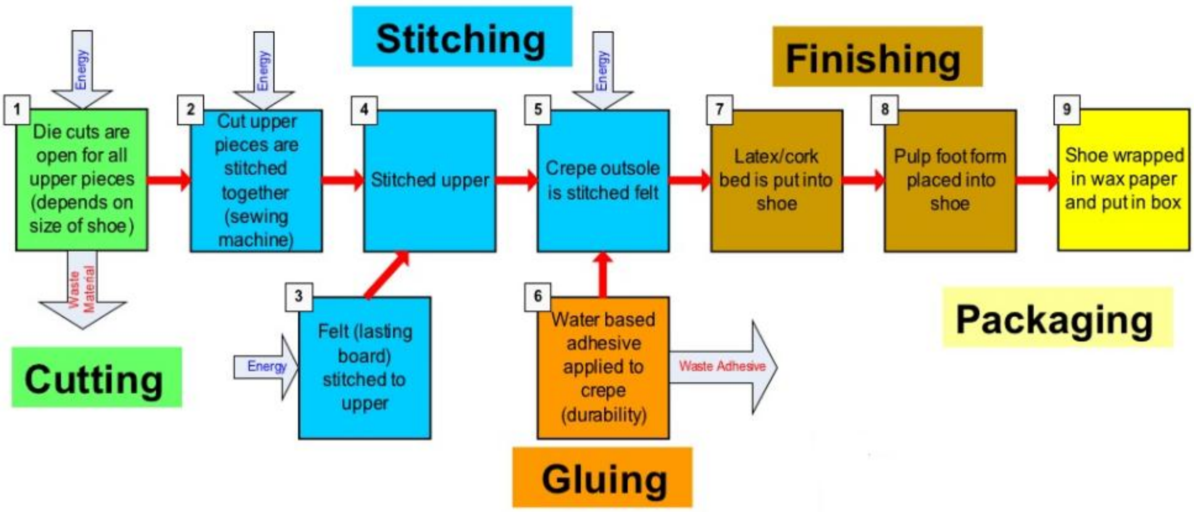

Figure 5 Flow of the steps to manufacture a shoe

The production process begins when the materials arrive at the warehouse of raw materials, which are inspected and checked for compliance with the conditions and standards that had been agreed with the supplier. The materials that come to the shoe manufacture are:

leather, lining, soles, laces, threads, individual boxes and packaging, solvents, glues and some products for the development operations.

The first step of the production process is the department of tackle, in which is formed carton to the plant according to the last floor. Die cut purchase the plant, so that no cardboard scrap generated. The shaping of plants is done with the help of a machine using a mechanical press to give the plant a way; this task also takes advantage of the machine action to paste a transfer to the sole with the company logo.

An alternating phase within the production process within the company is making plastisols. The plastisol is a polyvinyl chloride (PVC), resin mixture composed of a plasticizer and other additives. This product is liquid at room temperature and is white. In this case the plastisol obtains its colour by adding a natural dye and is subsequently poured into a steel mold to be heated by direct flame as in an oven (this is to solidify the liquid, which is achieved at a temperature is between 160 ° C and 200 ° C). The mold is heated for about one minute and placed in a container with water, to facilitate handling and avoid burns. To carry out this activity the use of LP Gas for the stove is required, so the company has a stationary tank with a capacity of 80 liters, which is located on the roof of the company.

The next stage is the cutting area. To cut the skin is used as a measure die cut established with the aid of a specific cliken machine. Once the piece has die cut, lowers the area where it is to sew, this in order to unite the pieces that do not form lumps that are uncomfortable when using the shoe. Within the production process there is embroidery area for the model that requires it. The embroidery is stitched with an automatic machine. Then the pieces are sent to the area of stitching.

When assembled skin parts in the backstitch area, which make up the structure of the shoe, this is done with electrical sewing needle and two pole needle to conform quilted the shoe, then passed to an area that is inspected for any deficiencies by cutting down or stitching. Besides this, it gets a buttress and depending on model, it can be added an eyelet part on the leading trimmings.

Cutting is taken and placed in the forming machine which will shape and give consistency to what will be the heel. The heel is then passed to the machine that is responsible for giving structure to the tip and sides with the help of the mold. This is achieved by cutting overlaid with the mold and machine stretch handles cutting and pasting the carton plant with a thermoplastic. An intermediate stage mounted in the operations described above is the preparation of the mold. This is done by placing a cardboard plant with the shape of the number corresponding to the cut and taped with a thermoplastic, which are used as mentioned above at the time of mounting the tip and sides. Once the cut is mounted on the last, is passed to the bonding area in which the first sole is halogenated in order to clean and apply glue.

Furthermore the shoe is carded to penetrate and cut the glue to achieve better cutting and addition between the sole.

When have halogenated the sole, smearing glue is like cutting and passed to a stabilizer oven to speed the drying time, by cutting out the sole of the furnace. Glued with the aid of a machine exerts pressure on the sole and the shoe that is in contact with the sole.

Leaving the shoe gluing machine is passed to an oven to leave stabilizer in normal shoes. Mold is removed and passed adornment. In the area of ornamental finish is given final details, after lists to send shipment. Finally on boarding larger boxes are used to pack individual boxes with shoes, ready to send to the client.

3.3 MÉXICO FOOTWEAR

México footwear industry is increasing its export trade enormously. The industry is dominated by small firms which are limited, however, by unstable supplies and little knowledge of the export market.

Figure 6 Shoemaker Monument in León, México.[1]

In this case the company Aretina gave information about their production process, materials, supplies, transportation, energy and water consumption, for a style of footwear made by the company.

The company is located in the city of León, Guanajuato, México, which is the city with the highest concentration of companies involved in leather, footwear and procurement within the territory. Providing the

[1]http://www.flickr.com/photos/this_is_sadik/2964188295/

largest footwear production in the country, with 57.8 percent of the total, using the 2.4 percent of total employment in manufacturing industries.

Figure 7 León, Guanajuato, México[2]

Footwear production in León has the advantage of close proximity to final demand and is located near cities with strong industrial development and therefore a high purchasing power: Guanajuato, Celaya, Aguascalientes and Queretaro are a few examples. It also has strong chains, as in the case of local or regional tannery.

The agglomeration in the production of footwear in León represents a natural cluster having an integration of industrial chain which links the raw materials and other inputs to the production of footwear. (Hernández, 2009).

3.4 WORLD FOOTWEAR INDUSTRY

The demand for shoes will never decrease, due to daily use of these and rising living standards, means that proportionally increase their global demand. The most striking phenomenon of the shoes industry in the past decade is the rise of China as a major winner and leader in capturing new markets. This dramatic rise has spread the view that the factor of competitive advantage in the industry is the abundance of cheap labour and raw materials.

This explanation obscures the dynamics of competitive play in a market increasingly differentiated and supports, of course, more than one strategy. For México, it is essential to view or determine, from the perspective of the global sphere its own strategy to become more competitive.

The worldwide consumption of footwear is estimated to be in excess of 20 billion pairs of shoes per year. To date very little work has been done to develop material recycling solutions for mixed footwear

[2]http://8congreso.delasalle.edu.mx/direccion.html

products. In fact less than 5% of end-of-life shoes are being recycled, with most being disposed of in landfill sites around the globe.(Lee and Rahimifard, 2012).

3.5 ENVIROMENTAL STATUS OF FOOTWEAR

The vision of 'Zero Waste to Landfill' thus remains as one of the major challenges of 21st century for the footwear sector. This target is very ambitious as currently less than 5% of the 20 billion pairs of shoes produced worldwide every year are recycled or reused (World Footwear, 2005; SATRA, 2003).

A product has several ecological, social and economic impact aspects, as analyzed, starting from the raw material extraction, manufacturing, distribution, use and final treatment. It affects the environment when taking such resources or emissions discharged directly into the ecosphere. These effects can cause environmental problems such as global warming, smog or water eutrophication[3].The recycling strategies relate to providing secondary raw material for a new shoe or other applications (building roads, toys, packaging, etc.)

3.6 STRATEGIES OF END-OF-LIFE FOOTWEAR (EoL)

In the next figures it can be seen the different end-of-life scenarios. In the first figure, explain the different EoL scenarios of the footwear products depending on the containing materials that can have relatively outlines recycled value. There are four main EoL options that can be considered for postconsumer footwear products: landfill, incineration/gasification, reuse and recycling. For each EoL are various environmental impacts, economic benefits and technical requirements to be considered.

[3]The process by which a body of water becomes enriched in dissolved nutrients (as phosphates) that stimulate the growth of aquatic plant life usually resulting in the depletion of dissolved oxygen. www.merriam-webster.com

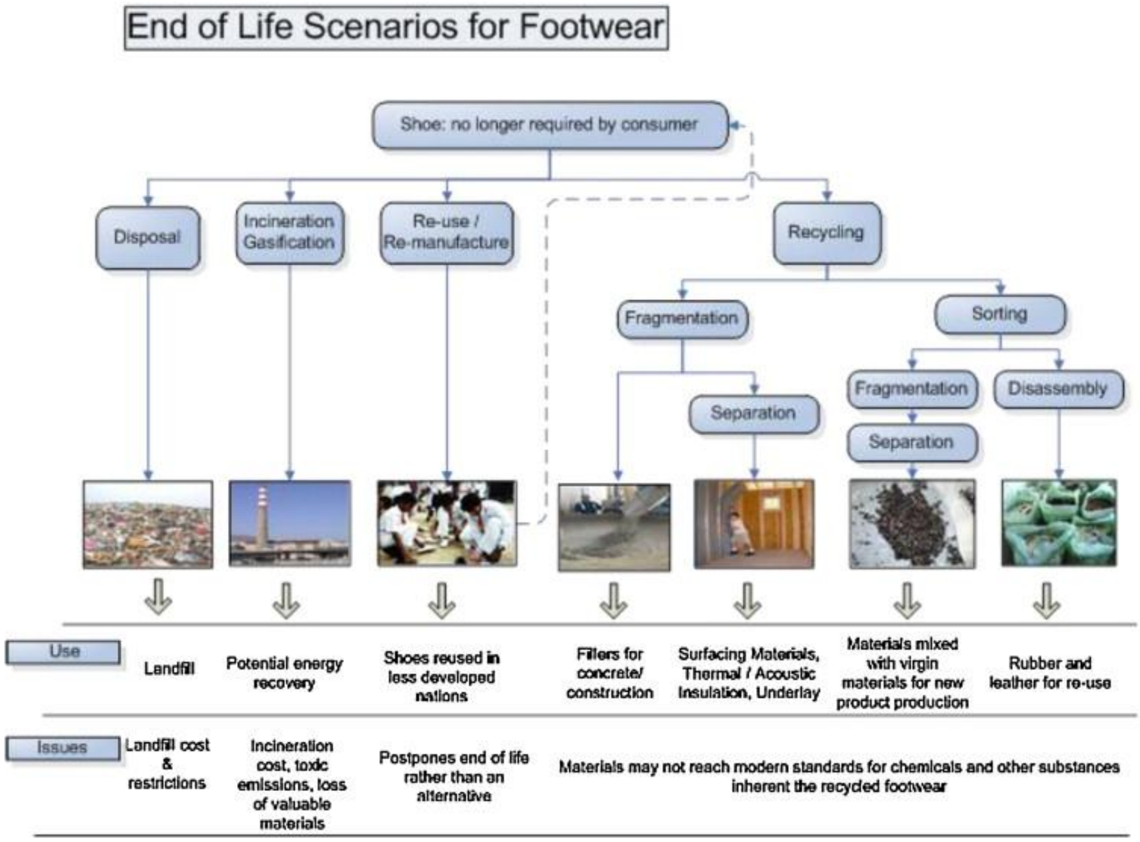

Figure 8 End of life scenarios for postconsumer footwear products(Lee and Rahimifard, 2012).

Figure 8 shows how can be applied the textiles, rubber, foam and leather fraction separation.

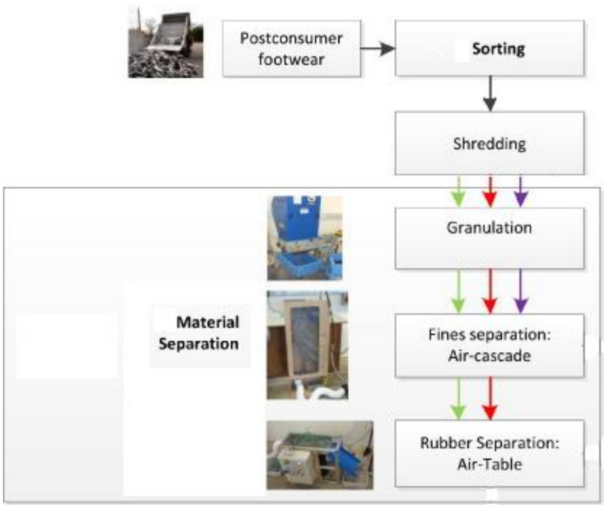

Figure 9 Recommended footwear recycling process flow (Lee and Rahimifard, 2012).

The current recycling solutions available for various types of waste in the footwear sector are depicted in Figure 9 and are briefly described in the following sections. The response of the footwear industry to the growing problems associated with the waste generated by the manufacture of the shoe is very little. Creating solutions to this problem can be a big improvement for the environmental and shoe manufacture.

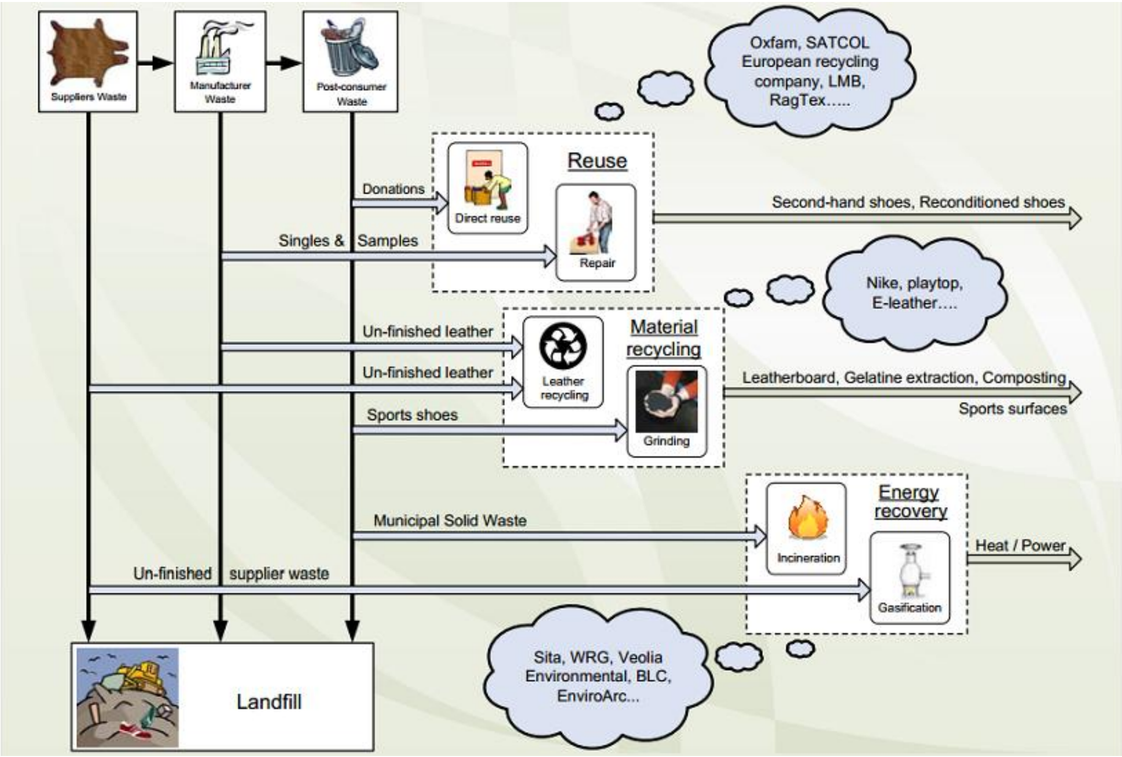

Figure 10 Current recycling solutions(Rahimifard et al., 2007)

3.7 ECO-DESIGN FOOTWEAR

Product design determines most of the environmental impacts that a product will potentially have during its life cycle. Design choices such as type of materials and manufacturing processes define whether end-of-life strategies for closing the loop of the materials will be potentially feasible or not, influencing the waste and pollution generated by our consuming society. Eco-design can help in the substitution of materials for others with less environmental impact. In the next figure we look at an eco-shoe manufactured by Astorflex in Italy.

Figure 11 Eco-shoe sample of Astorflex, Italy.

The following criteria can be considered to manufacture an eco-shoe:

- ✓ Energy consumption
- ✓ Reduction of water consumption
- ✓ Use of recycled material
- ✓ Limitation of water pollution
- ✓ Have materials of high quality
- ✓ Reduction of air pollution
- ✓ Exclusion of the use of substances harmful for the health and the environment
- ✓ Last at least for a year lifespan
- ✓ Performance and durability
- ✓ Advice to consumers
- ✓ Limitation of toxic and other residues in the shoes

For making this eco-shoe, we need to know and change the materials and some manufacture aspects for obtain less impact in the environment footprints. Some of this information was provided by the Astorflex Shoe Manufacture, in Italy, that currently manufactures eco-shoes.

- Vegetal tanned leather, with tanino, mimosa and chestnut, without use of chemicals.
- Natural rubber resin for the sole.
- Fiberglass in the tongue.
- Solvents and glues based in water.
- Textiles without polyester and polyurethane.
- Used recycled material
- Reduce the normal energy consumption, with a renewable energy. (can start with some percentage)
- based chemicals hexane
- Latex foam
- Remove fabric and interlining

The major environmental impacts of leather production originate from liquid, solid and gaseous emissions resulting from the consumption of rawhides, energy, chemicals and water. (Joseph and Nithya, 2009). The authors reported that only a few slaughterhouses possess waste management facilities and hence, average, country specific data were used for waste management part of slaughtering, tanning and finishing activities for the study. The transportation of the main materials like hides, water, salt, chromium salt, and fuel is important to be considered for further analysis.(Joseph and Nithya, 2009)

This was developed based on the material flow data generated during this study for the leather required to make a pair of shoes.

Extrapolation of the data over 776 million pairs of leather footwear reveals that about 2.25 million tons of chemicals are used and most of which are released to the environment, consequently polluting the locations surrounding the tannery clusters. Similar extrapolations of other parameters and their impacts on the local and global environment make it clear that there is urgent need to take dramatic actions to help to ensure that the leather production industry reduces its negative environmental and human health impacts. In making such reductions, the leather production industry can help to contribute to societal sustainability.

3.8 FORCES OF ECO-DESIGN

The concept "Driving Forces of Ecodesign" can be explained as those factors internally and externally to encourage a company to develop products environmentally (van Hemel, Cramer, 2002).

Table 4 Driving Forces of Ecodesign (van Hemel, Cramer, 2002).

INTERNAL FORCES	EXTERNAL FORCES
• Government action • Lack of resources • Market • Competence • Social environment • Sector Organizations • Suppliers	• How to understand the "Responsibility" of managers • The need to improve the quality of product • The need to improve image company and product • The need to increase motivation staff

The driving forces external to the firm, which are indicated in bold, take on a special importance as they relate to demonstrate the importance of understanding the perceptions and beliefs of consumers when choosing a product.

3.9 FUTURE SUGGESTED STUDIES

The sustainable solutions and developing products for the future have to give attention and manage many kinds of aspects, like materials, hand-made, production procedures, design models, transportation, appropriate measurement, among other tools that need to be developing.

To optimize the full life cycle of a product, finding the best way to fulfil their roles and the least impact on the environment, considering also all auxiliary processes. Instead of focusing solely on the individual product, the whole system has to be continuously evaluated and improved. Designing footwear to reduce its environmental impact throughout their life cycle, an eco-designed product that have a similar quality to or greater than the equivalent in the market, with the added value of being an innovative and more environmentally friendly.

4. RESULTS

The following tables visualize the results obtained through literature of scientific articles, the company Aretina Company and the database of SimaPro software.

Table 5 Footprints for one pair of the reference shoe

Processes	Materials	Quantity (Kg)	Footprints for one pair of shoes		
			Energy (MJ)	Water (L)	CO2 eq. (Kg)
Textile production	Fabric and interlining	0.04200	1.60238	2.50492	1.14317
Plastic production	EVA	0.02500	0.02275	0.08778	0.05302
	Laces	0.01200	0.07072	0.39338	0.06857
Cow leather production	Cow leather	0.14000	0.18194	1.18209	0.01730
Pig leather production	Pig leather	0.09300	5.91E-05	n.d.	0.00216
Chemicals production	Glue	0.17000	n.d.	n.d.	0.13456
	Solvents	0.05100	0.02488	0.08512	0.11673
Rubber production	Sole	0.37000	0.75416	2.45411	0.99134
Paper production	Paper	0.27000	12.14909	1.66733	0.79083
Transport 12 Km (incl. Fuel cons.)			2.16E-05	1.21E-04	6.33E-04
Shoe manufacturing		One pair of shoes	3.24000	0.03600	n.d.
Total			**18.04601**	**8.41085**	**3.31833**

In Table 5, the calculations were based on weight for each material. The total energy footprint is18.04601MJ; the total water footprint is 8.41085 liters; and the total carbon footprint is 3.31833Kg CO2 eq.

The greatest impact in the energy footprint is in the production of paper with a 12.15 MJ, which produces the box, and paper packaging. The smallest energy footprint is in the production of pig leather production 5.91 E-05 MJ.

The two largests water footprints are in the production of textile fabric and interlining 2.50 L and in the rubber production to make the soles of TR (2.45 L).

The total carbon footprint(3.32 kg of carbon dioxide equivalents), is roughly the same to produce 1 kg of pork meet from the farm, which produces 3.5 kg of CO2 eq. (Dalgaard, 2007)

3.6 kg CO2 equivalents per 1 kg of pork Danish, corresponding to emissions management a distance of 10 Km in a typical passenger car. (Dalgaard et al., 2007b)

The major impact of this footprint is in the production of textiles and fabric manufacture interlining with 1.14 kg and less impact on the transport 6.33E-04 kg seeing distance emissions are very small, whereby influence transport minimally. Without taking into account in these calculations that raw hides are brought in United States. With 2200 pairs produced reference style for the period of one month, the results in footprints are:

Energy: 39,600 MJ

Water: 18,502 L

CO2eq: 7,340 Kg

Table 6 Normalization of the ecological footprint of a reference pair of shoes

Footprints for one pair of shoes - NORMALIZED VALUES			
Materials	**Energy (MJ)**	**Water (L)**	**CO2 eq. (Kg)**
Fabric and interlining	1.32E-01	1.00E+00	1.00E+00
EVA	1.87E-03	3.50E-02	4.64E-02
Laces	5.82E-03	1.57E-01	6.00E-02
Cow leather	1.50E-02	4.72E-01	1.51E-02
Pig leather	4.87E-06	0.00E+00	1.89E-03
Glue	0.00E+00	0.00E+00	1.18E-01
Solvents	2.05E-03	3.40E-02	1.02E-01
Sole	6.21E-02	9.80E-01	8.67E-01
Paper	1.00E+00	6.66E-01	6.92E-01
Transport 12 Km (incl. Fuel cons.)	1.78E-06	4.83E-05	5.54E-04
Shoe manufacturing	2.67E-01	1.44E-02	0.00E+00

In Table 6 the values were normalized to compare the different ecological footprints of water, energy and CO2 equivalents each material. Dividing the values of each footprint materials, for the largest value obtained.

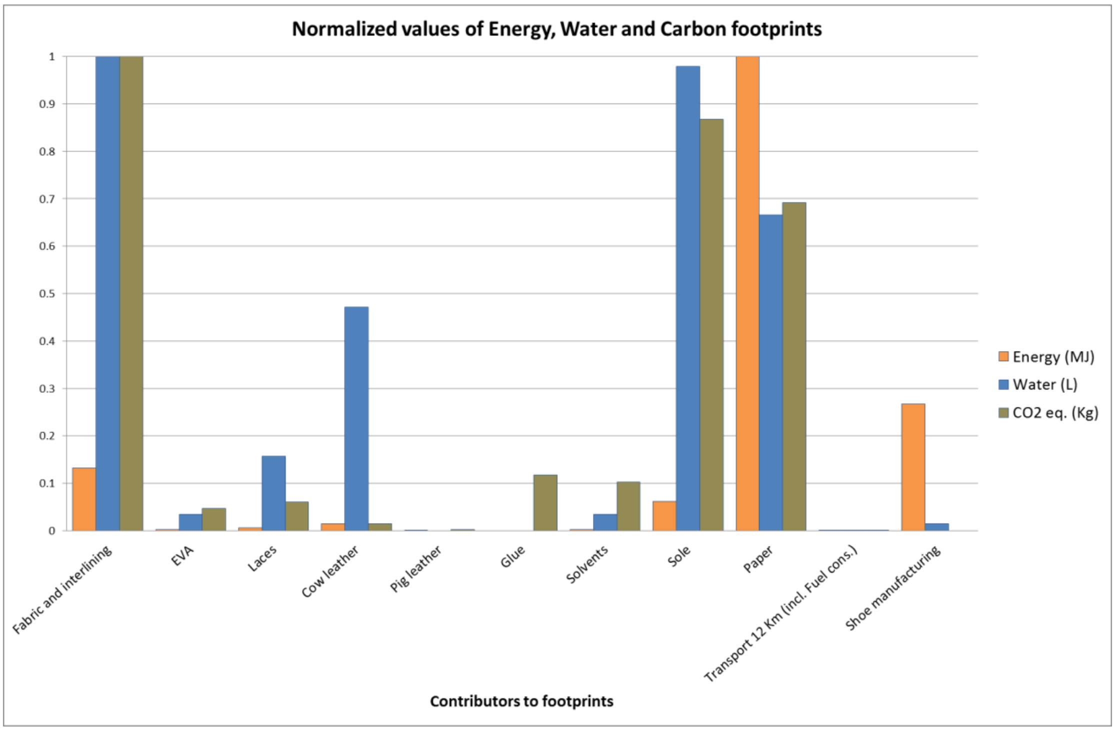

Figure 12 Normalization of energy, water and carbon ecological footprint

Figure 12 shows graphically the normalized values, the results of which are outlined in Table 7.

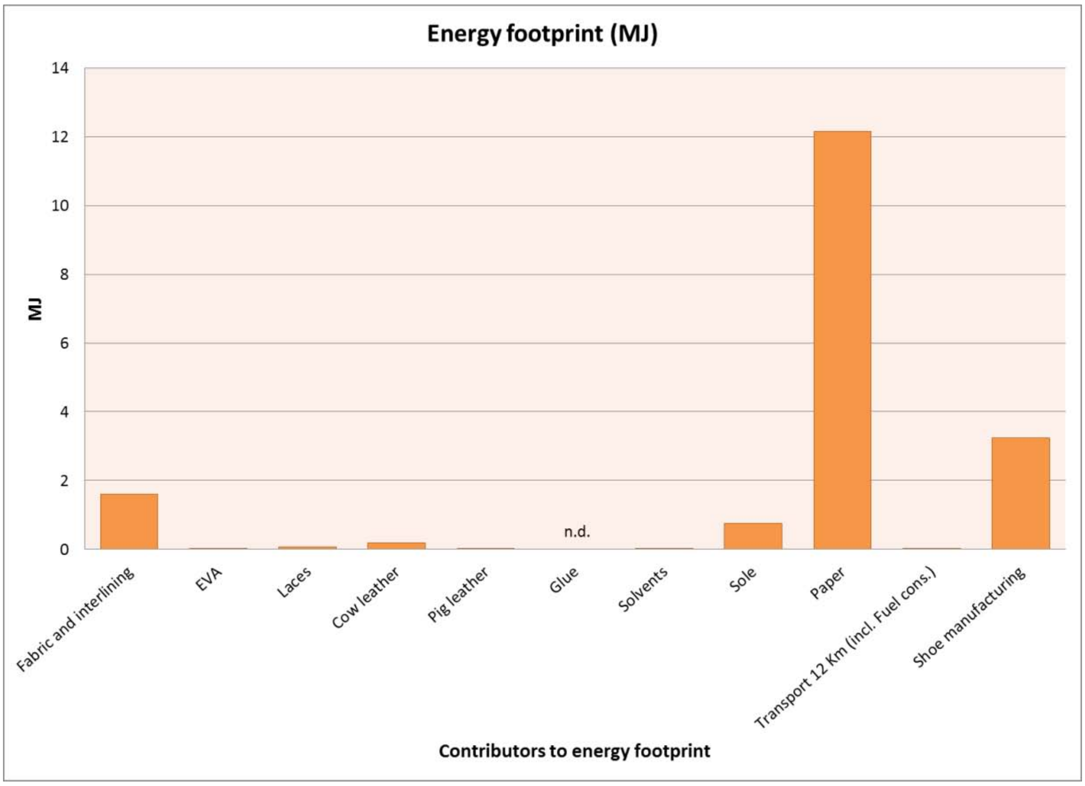

Figure 13 Energy Ecological Footprint

Figure 13 shows that paper production is the highest impact, combining this result with CO2 emissions in the energy consumed due to the use of biomass for energy life cycle inventory. Without having information of the energy used in the adhesives manufacture.

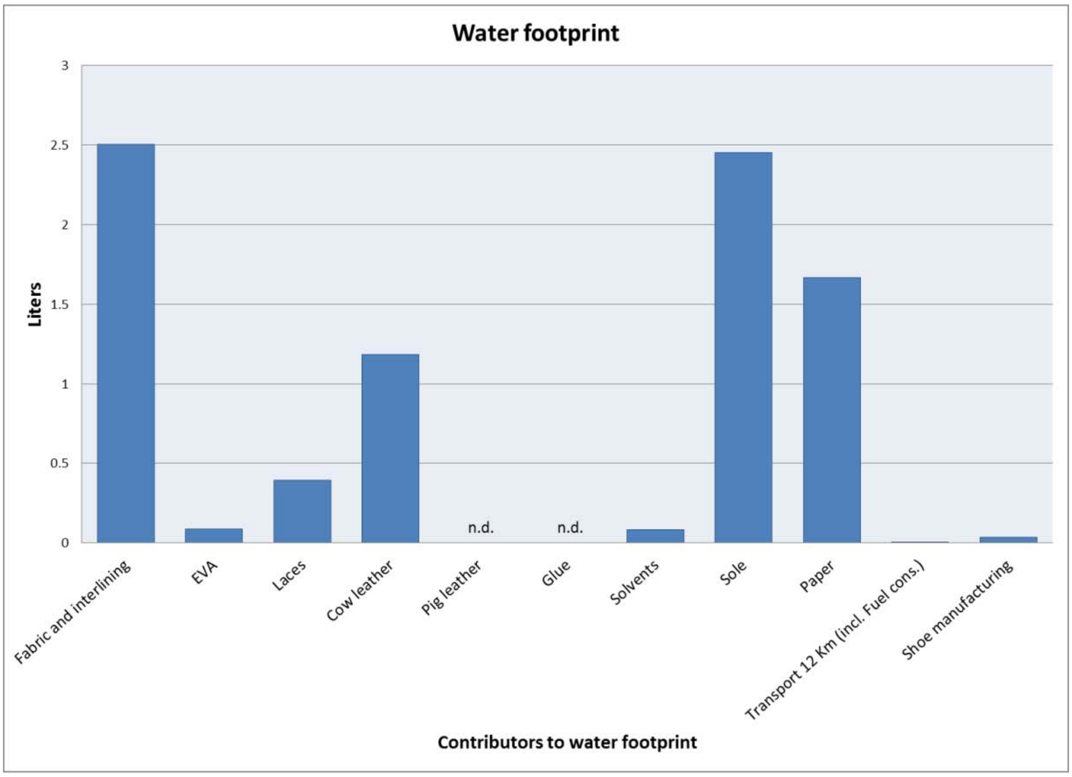

Figure 14 Water environmental footprint

In Figure 14 has its greatest impact on the footprint of the water in the textile, to manufacture the fabric and interlining having a nearly equal level with the manufacture of the sole. No information for the production of pig lining and adhesives was available.

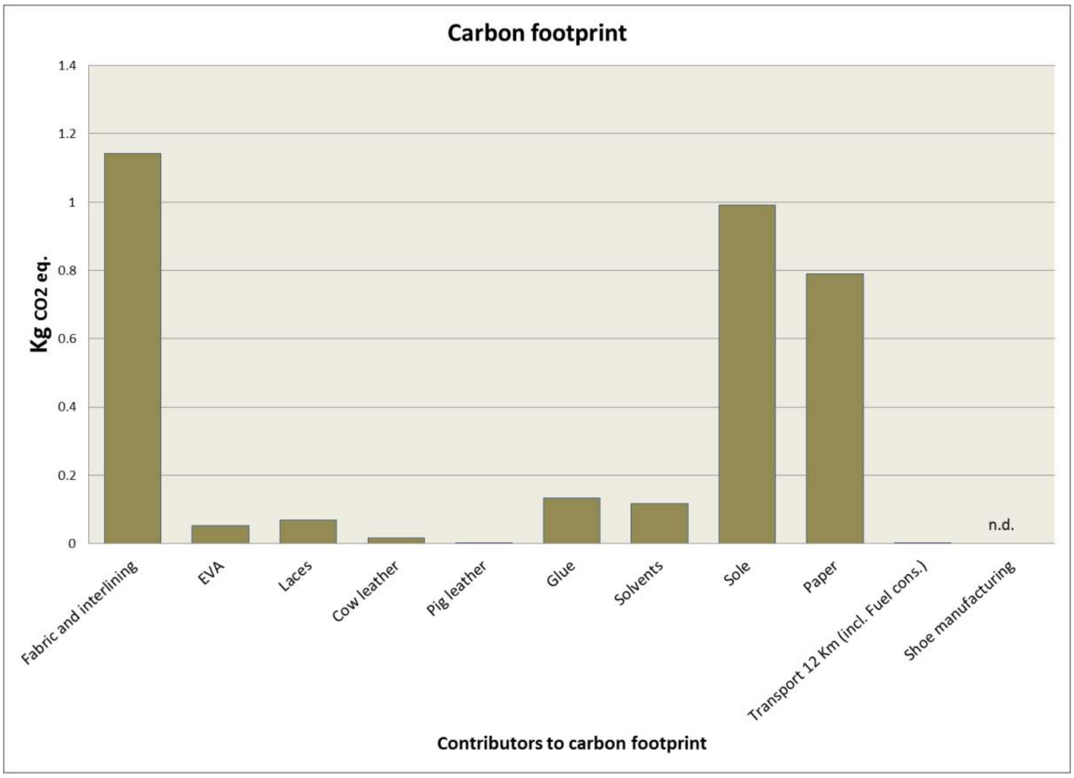

Figure 15 Carbon Footprint

In Figure 15 we see the greatest impact on textile production and water footprint for the manufacture of cloth and interlining, followed by the production of the sole and the paper. Without having information for shoe manufacture. Due to this reason I suggest a study on CO2 emissions generated by the manufacture of footwear.

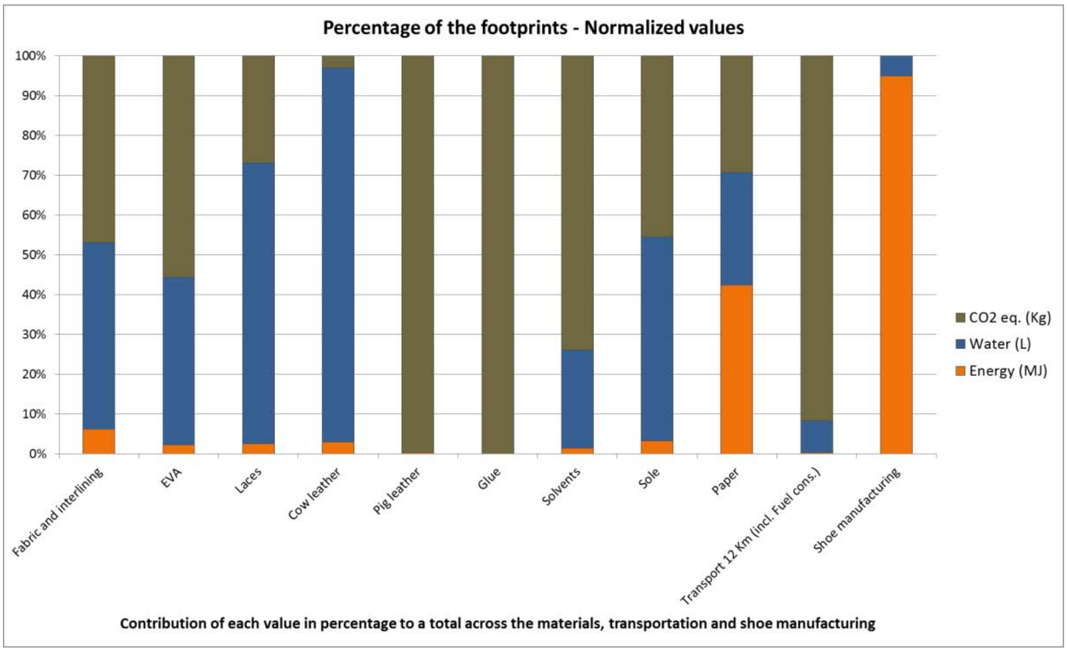

Figure 16 Percentage of Footprints, Normalized values

In Figure 16 we see the greatest impact on textile production and water footprint for the manufacture of cloth and interlining, followed by the production of the sole and the paper. Without having information for shoe manufacturing. Due to this reason I suggest a study on CO2 Emissions generated by the manufacture of footwear would be necessary.

5 DISCUSSION

Footwear manufacturing uses environmentally harmful materials such as chromium tanned leather, chemical-based adhesives and synthetic rubbers. The production and disposal of these materials release greenhouse gases, as well as toxic pollutants which can negatively impact human health and natural ecosystems. The magnitude of the footwear industry contributes to environmental problems significantly.

Eco-labelling system is an option to evaluate the environmental impact by regulations and tools that account within the shoe, but cannot estimate the water and energy impacts in the footprints. That is the reason why choosing to analyze this emissions of the footprints with performed Life Cycle Assessment (LCA), supply chain analysis and End-of-Life (EOL) evaluation. Using SimaPro for more data and analyse this emissions by calculations in excel, focus the change in the material production, assembly phase of their supply chain and redesign with an eco-design or eco-shoe that generate less emissions.

The Volatile organic compounds (VOCs) are emitted as gases from certain solids or liquids[4]. Using glues and adhesives is part of this problem, and the question is how we can manage this. Can it be changed by replacing for glues and adhesives with aqueous base?

The rethinking system to manufacturing eco-shoes for obtained the goals and objectives of this study case, in order to envision new market opportunities, having approach to reduce the use of natural resources, maintaining economic growth, replaying this eco-shoes, which are an alternative to create a radical shift in our economic and environmental orientation, rather to produce more normal shoes, starting this project and continue the how to produce an eco-shoe that emit less VOCs is the main purpose, with this proved results we can improve the consumer´s experience and share the rethinking of the environmental, changing the lack of knowledge on this subject of environmental impact. Is a big challenge to the footwear manufacturing companies, consumers and customers to get a better ecological product that can take care more of our planet.

[4] http://www.epa.gov, 2013.

6 CONCLUSION

The challenges in this study were to obtain the data collection of the specific materials and the chemical compositions. Also the water and energy used to manufacture the different materials and the shoe production.

The weaknesses of this study are that do not analyze the toxicity of the materials. In the other side, the strengths of this study are the analyzed three different footprints of a pair of leather shoes. A possible future research is to evaluate the toxicity of the materials, and also to analyze the difference of producing an eco-shoe with ecological materials, to see the difference of this three footprints impact.

In the life cycle inventory of materials of a reference pair of shoes, we see that the first and greatest impact of ecological footprints is 18.05 MJ of energy consumed mainly due to the production of paper and textile production. Secondly ecological footprint is 8.41 liters water, mostly by the textile and the sole and third carbon equivalent footprint 3.32 Kg with most in textile production and the sole. It is important to note that textiles have the two highest impacts (water and carbon) on the three ecological footprints.

Textile production is the number one issue impacts on water footprint and CO2 eq. The use of recycled water treated helps to reduce this impact.

To reduce the impact on the ecological footprint of energy, is you need to cut through the use of renewable energy in both the manufacture of footwear, such as that used to produce the different materials used.

In this study the transport emits minimal impact on the three ecological footprints. Regardless of the raw hides are purchased in the United States.

In the analysis of the ecological footprint of water, carbon and carbon equivalent of a pair of shoes showed that important areas for the development of green footwear are the sole, fabric, interlining and the packing for shoes.

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GLOSSARY OF TERMS

A Life Cycle Inventory (LCI) is a collection of data sets that quantify energy, water, raw material requirements, air emissions, waterborne effluents, solid wastes and other environmental releases that occur throughout the life cycle of a product, process or activity.(Foundation)

Carbon footprint (CF): – also named Carbon profile - is the overall amount of carbon dioxide (CO2) and other greenhouse gas (GHG) emissions (e.g. methane, nitrous oxide, etc.) associated with a product1, along its supply-chain and sometimes including from use and end-of-life recovery and disposal.[5]

Eco-design: is a tool to reduce the impact during the life cycle of products that has evolved primarily through engineering and Life Cycle Assessment LCA.

Eco-labelling (or eco-labels): environmental labelling refers to manifestations of the environmental aspects of a product or service.

Ecological Footprint: the metric that allows us to calculate human pressure on the planet and come up with facts.[6]

End-of-Life (EoL): is a term used with respect to a product supplied to customers, indicating that the product is in the end of its useful lifetime and a vendor will no longer be marketing, selling, or sustaining a particular product and may also be limiting or ending support for the product. In the specific case of product sales, the term "end-of-sale" (EOS) has also been used.

Environmental aspects: (AENOR, 2004), are all those elements or functions that can interact with the environment during its life cycle, and are directly associated with the product. An environmental aspect is any factor that can cause environmental impact.(Albelda-Reyes et al., 2011)

Footwear: refers to garments worn on the feet, for fashion, protection against the environment, and adornment.

Greenhouse gases (GHG): are gases found in the atmosphere that are capable of absorbing infrared radiation emitted from the Earth's surface.[7]

5

ISO 14040 defines the term "product" as both "goods" (e.g. consumer goods, intermediate goods) and "services" (even complex services like events, conferences and exhibitions).

6 http://www.footprintnetwork.org

7 http://www.climatechangeconnection.org

Life Cycle Assessment (LCA): concerns a comprehensive evaluation of all "upstream" and "downstream" flows and impacts throughout the life cycle of a product or a process, is a cradle to grave approach for the potential environmental impacts of a product system over its full life cycle (ISO, 2006).

Life-Cycle Thinking (LCT): is the basic idea behind the product-based indicators.(Dalgaard, 2007)

Product Environmental Footprint: is a multi-criteria measure of the environmental performance of a good or service throughout its life cycle.

System Boundaries: define which parts of the product life cycle and which associated processes belong to the analysed system.(II and GUIDE)

Tanning: is the process of transforming the animal skin (a natural renewable resource to leather (a market material used in the manufacture of a wide range of products).(Rivela et al., 2004)

Toxicity: is the degree to which a substance can damage an organism.

APPENDIX

The next table A.1 indicate the general data for the references shoe and general production proportionate by Aretina Company.

Table A.1 General data from Aretina Company for the study case.

General Data for Aretina Company in México	
Production of the reference shoe per month	**Quantity**
Per month	867 pairs
Production of that style	2200 pairs
Density of the Glue	0.856 gr/ml
Energy per pair	0,90 kw/h
Water per pair	36 g

Table A.2 indicate the different glues and solvents for the production of this referent shoe depend of many factors like density, based in oil or water that in this case is in oil.

Table A.2 Specificationsof adhesives and solvents

Specifications of adhesives and solvents	Volume (ml)
Glue FT-950 Fijabuck (1 Lt per 100 pairs)	10
Glue WX-600 (17 Lt per 1000 pairs)	59
Glue GF-400	147
Glue ATF-ID-587	59
GlueProbst E-2095	10
Solvent JN-210 espeable	59

Table A.3 shows the materials and waste generated in each stage of the shoe manufacture.

Table A.3 Waste material in each process

List of materials and process residues			
Stage	**Inputs**	**Waste**	**Drivingreference**
Warehousefeedstock	Hides and derivatives, textile and / or synthetic. Cartons containing adhesives, solvents, paints, pigments and / or solvent-based inks. Cardboard, paper, plastic bags.		

Modeling	Catoncillo, paper, tape.	Scraps of cardboard and paper.	1
Gear	Leather helmets and buttresses material, cardboard, synthetic.	Powders and leather sole cuts and / or synthetic materials for helmets and buttresses, cardboard and chipboard plant.	1
Cut	Skin and derivatives, textile and / or synthetic.	Scraps of leather, textiles and / or synthetic.	1
Preliminaries and Backstitch	Adhesives, tow, oils, solvents, inks and / or threads.	Impregnated tow adhesives, oils, solvents or solvent based inks. Packaging empty solvent based adhesives, oils, solvents or solvent-based inks. ___ Cuts or skin lining powders, synthetic or textile. Cones of thread.	2 ___ 1
Mounted	Solvents, glues, oils, pigments, tow, inks and waxes, plastic bags, caps and abutments, nails, soles and synthetic leather.	Powders cuts: leather, sole leather and synthetic textile material for helmets and buttresses, cardboard and chipboard plant. Plastic bags and nails. ___ Empty containers of solvent-based adhesives, oils, solvents and solvent-based inks. Solvent-impregnated tow. Pigments and / or solvent-based inks. Solvents dirty.	1 ___ 2
Adornment	Solvents, pigments and inks, rags, cardboard and paper.	Cardboard and paper. Scraps of leather lining, synthetic and / or textile. ___ Empty containers of solvents, pigments and / or solvent-based inks. Impregnated tow solvents, pigments and / or solvent-based inks. Solvents dirty.	1 ___ 2
Maintenance	Tow, flannels (rags), oils, lubricants, solvents.	Spent lubricating oils, tow and rags soaked with oil or solvent.	2

1) Non-hazardous waste, compliance with the provisions in paragraph III (non-hazardous) and section IV.

2) Hazardous waste, complying with the provisions in paragraph III (Hazardous Waste)

In Table A.4 describe in which step or area is the used the specific material to manufacture the reference shoe.

Table A.4 Step that is used each material.

			Production: step that we use that material						
Materials of a shoe:	**Materials come from:**	**Level of waste**	**1. Stock of raw materials**	**2. Modelation**	**3. Tackle**	**4. Court**	**5. Preliminar**	**6. Mounted**	**7. Adornment**
Hides and derivates	Cow	High	X			X	X	X	X
Skin and deribates	Cow	High	X			X	X	X	X
Leathersoul	Cow	Low	X			X		X	
Textil lace	Oil	Low	X			X			X
Buttress	Oil	Low	X			X	X	X	
Eva foam	Oil	Medium	X		X	X	X	X	
Pigleathertemplate	Pig	High	X			X	X	X	
Scraps of cardboard/paper	Tree	Medium	X	X					X
Indianpaper	Tree	Medium	X						X
glue/adhesives	Oil	Medium	X					X	
solvents/paints	Oil	Medium	X					X	X
leatherhelmets	Cow	Medium	X			X		X	X
tow/flannels/rags	Cotton/Plastic	Medium	X					X	X
oils/lubricants	Oil	Medium	X					X	X
Tape	Oil	Medium	X	X					
Threads			X				X		