





# Managing the Environmental Impacts of Small Businesses Manufacturing Women's Leather Dress Footwear in Colombia

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## Abstract

Given the growing global demand for footwear, its increasingly shorter life cycle, the billions of pairs of shoes sold and the negative environmental impacts in the shoe supply chain, this paper explores the negative environmental impact in the stages of the life cycle of leather dress footwear and proposals to reduce them, taking the process of manufacturing handmade women's leather dress shoes in small Colombian companies as an example. The MET (material, energy, toxicity) matrix was used for the qualitative life cycle analysis along with information from unstructured interviews and from observing the production process. The

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actions to reduce environmental impacts were processed via a systematized information search. The results show that production and end of life stages have the greatest impacts, and actors in the supply chain must be integrated to effectively manage the materials. Furthermore, proposals to reduce negative environmental impacts were presented as a way to improve environmental performance.

**KEYWORDS:** qualitative life cycle analysis, footwear, eco-design, business environmental management, sustainability

## Introduction

The global fashion industry produces highly negative outcomes for the environment, and it is recognized as one of the highest impact industries on the planet (Pal and Gander 2018). This industry encompasses the design, manufacturing, distribution, marketing, retailing, advertising, and promotion of all types of apparel and accessories from haute couture and designer fashions to ordinary everyday clothing (Čiarnienė and Vienožindienė 2014). Some of the actors in the industry perform negatively environmental impacts like high water usage, excessive chemical usage from treatments in dyeing and preparation; and the disposal of large amounts of waste (Pal and Gander 2018). Accordingly, high energy consumption and carbon emissions are stated by Palamutcu (2015). Furthermore, the agriculture of fibers such as cotton has changed the land cover compromising food security (Erdinger, Hollert, and Eckl 2019). In addition, social issues such as low wages and poor labour conditions negatively impact the social dimension of sustainability of part of the industry (Luz 2007).

However, within the fashion industry, there have been interesting alternatives and movements to change the current reality and its negative impacts on environmental quality and human well-being, e.g. the sustainable or eco-fashion movement (Gwilt and Rissanen 2011), slow fashion (Fletcher 2010), or the Fashion Revolution movement initiated following the Rana Plaza disaster in Bangladesh in 2013 (<https://www.fashionrevolution.org/>). Likewise, some companies are starting to change their business model due to increasingly stringent global environmental policies and regulations that constitute nontariff barriers to trade and because consumers are more aware of the environmental impact of products (Quintero-Angel et al. 2018). Nevertheless, according to Pal and Gander (2018) there is still a lack of scalable sustainable business models, since some of the initiatives or technologies adopted are contradictory to the achievements in competitiveness and value creation.

Particularly, since 1990, some initiatives from the footwear industry have reported modifications on the effective use of energy and materials; as well as reductions on the use of hazardous materials during the production process which have a positive impact on the life cycle of

footwear (LCF) (Staikos and Rahimifard 2007a, 2007b). For example, Pacheco-Blanco et al. (2010) used life cycle analysis (LCA) to evaluate the impacts of footwear production in Spain, noting that the assembly stage has the greatest impact on the environment. LCA has also been used to analyze the environmental impact of Swedish shoe consumption, showing that footwear impacts can be affected by type and amount of material used in production (Gottfridsson and Zhang 2015). The authors showed it can be affected by the total consumption, as well as the country of production, due to differences in legislation and industrial standards for environmental protection. Cheah et al. (2013) calculated the carbon footprint of a pair of sports footwear as equivalent to  $14 \pm 2.7$  kg CO<sub>2</sub> considering its life expectancy from the cradle to the grave. They also estimated that 68% of emissions are generated in manufacturing and 29% in processing materials.

Despite efforts to reduce the negative environmental impact (NEI) of footwear, important changes are still required to develop and use biodegradable materials in the design, production operations and consumption of footwear. For example, while fashion consumers profess concerns about sustainability issues, there exists a gap between these concerns and actual consumption decisions and behaviors (Han, Seo, and Ko 2017). Likewise, there are large amounts of unsold stock disposed of through incineration or landfill deposits (Pal and Gander 2018), as well as an increase in the amount of footwear used and a tremendous amount of post-consumption footwear in landfills worldwide (Staikos and Rahimifard 2007b). Therefore, consumers require information about the sustainability of footwear, the environmental management systems of the companies in the supply chain, and environmental information comparable to that available on a global scale comparable to world records (Pacheco-Blanco et al. 2018).

However, it should be noted that requirements for reducing NEI vary in the footwear industry, so, for example, athletic shoes are gaining more attention, and manufacturers are currently working to reduce the impact of source materials (Cheah et al. 2013), but other types of footwear, such as leather dress shoes, receive less attention from both academic scholars and practitioners. Likewise, there are important differences in reducing NEI in relation to business size and bargaining power with suppliers and customers, e.g. some small businesses are not pressured by environmental requirements from their customers, but other fashion suppliers are forced by powerful retail buyers to improve their environmental standards and to obtain accreditation (e.g. ISO14001) or are forced to implement sustainable processes, to reduce energy and water consumption in manufacturing, and to eliminate harmful chemicals (Talay, Oxborrow, and Brindley 2018).

In the case of Colombia, the growing commitment of businesses to reduce their NEI is evident; however, progress is still in its infancy and disparate among companies in the fashion industry. While some

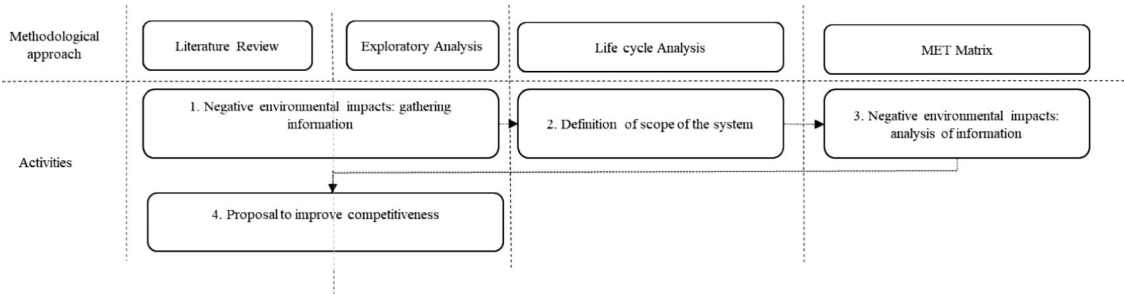
companies are involved in the latest trends in fashion, technological development and sustainability, others struggle to become certified and to comply with environmental and labor legislation. The latter is one of the most important challenges in the footwear sector in Colombia and other developing countries, as the majority of micro and small businesses engage in informal hiring, have work schedules that exceed the legal limits, pay below the legal minimum wage (Ministerio de Comercio Industria y Turismo 2012) and are not concerned about safety at work or the NEI and sustainability of production. In this context, the objective of this paper is to estimate the NEI associated with women's leather dress footwear in micro and small Colombian companies within the LCF stages from the design to the end of use for environmental performance improvement in each stage.

### **Footwear Sector in Colombia**

The footwear sector in Colombia is highly fragmented, with different companies with low participation in the supply chain due to the increase in the number of low-cost producers in the global market, which, except for products such as branded sports footwear and designer footwear, favors low brand recognition, making it relatively easy for new brands to establish viable supply chains (Euromonitor International 2017). Additionally, local suppliers recognize a threat in the increase in direct purchases from Asian suppliers in terms of both volume and value (MarketLine 2015). Local suppliers cannot compete on price and volume with global competition, and thus some have specialized in footwear for specific purposes, such as orthopedic footwear or local designer products (MarketLine 2015). Generally, producers are not distributors, so the supply chain is rarely integrated.

A major problem for local producers is the noncompetitive behavior of some distributors, who sell contraband products or products at prices below the cost of domestic production. Because of this situation, since 2012, the Colombian government has applied a tariff on garments and footwear entering from Panama. Additionally, to copy the designs, counterfeit and informal sales constitute a threat to the growth of the sector, despite the efforts of the Colombian government to control them (Euromonitor International 2017).

In terms of production clusters, such as those in the Restrepo neighborhood in Bogotá or around Bucaramanga, there are several small producers with marginal participation in the categories of footwear (Euromonitor International 2017). One of the characteristics of small producers and, in general, most companies in the footwear industry in Colombia is limited innovation (Alzate, Hurtado, and Lopez 2015), their low level of technological modernization and knowledge, and barriers to technological absorption, which translates into low productivity and low aggregate value (Ministerio de Comercio Industria y Turismo 2012).



**Figure 1**  
Methodological stages.

Likewise, currently, the local production of natural and ecological resources is limited, and there are difficulties in the supply chain, given that companies in the sector need a large amount of inputs and components, which are not always produced by local industry or in compliance with the quality and variety required. Therefore, producers and suppliers are forced to import supplies, such as ornaments, soles, heels, insoles, shoe trees, fabrics, tips and buttresses from Mexico, Brazil, Spain, Italy and China, among others, so in many cases, producers use the same supplies as their competition (Ministerio de Comercio Industria y Turismo 2012). Despite the reported difficulties, the footwear sector in Colombia exhibits a growing trend similar to the global trend, confirming the need to pay attention to the environmental effects of domestic production and imports.

**Methodology**

This study was carried out in four stages, as shown in Figure 1.

*i. Negative environmental impacts: gathering information:* The information regarding NEI was obtained through observation of the production process in three small leather footwear manufacturers’ workshops in the city of Cali-Colombia that produce between 80 and 600 pairs a month (Table 1). Additionally, videos of the process of making women’s leather dress footwear by some small businesses from different Colombian cities available on YouTube were observed: Diseños Angie (Posada 2014) and Vicky Tcherassi (Salcedo 2014) in Barranquilla, Bucaramanga (Sanchez 2015) and Calzado Beltrani (Freire 2013) and Taller Cordonier QMI (Quiroga-Cuevas 2017) in Cali.<sup>1</sup>

The observational categories were the stages of the production process, the usage of materials, waste generation (material, energy, toxicity), solid waste disposal, actions to reduce energy consumption and toxicity, equipment and tools used. Additionally, information was obtained from owners and shoemakers of the visited leather footwear manufacturers’ workshops through unstructured interviews. The interviews inquired about: the business model, the sales process, raw materials used, the

**Table 1.** Profiles of companies observed in Cali-Colombia during January and June 2017.

Company 1	Company 2	Company 3
Small enterprise under business to consumer (B2C) sales model through its own store and electronic commerce. It hires 4 employees. It produces up to 80 pairs monthly of fashion leather shoes for women with own design and leather accessories. The owner is the same manager and designer, who works on his own workshop under artisanal processes. The owner also acquires shoes from other workshops under maquila contracts, keeping his own designs. The workshop is equipped with a flat, post and grinding machine. The average sale price of a pair of fashion leather shoes: 70 USD.	Small enterprise under business to business (B2B) sales model and maquila contracts; which employs 7 people. The processes are artisanal and it produces fashion leather shoes for women with designs taken from the internet. Monthly production is about 600 pairs in its own workshop for local brands. It has 1 flat machine, 2 post machines, and 1 grinding machine. The average sale price of a pair of fashion leather shoes: 35 USD	Small enterprise under business to business (B2B) sales model and maquila contracts; which employs 4 people. The processes are artisanal and it produces fashion leather shoes for women with designs taken from the internet. Monthly production is about 200 pairs in its own workshop for local brands. It has a post and a grinder machine. The average sale price of a pair of fashion leather shoes: 30 USD.

supply chain, the production process, solid waste generation and disposal, and environmental performance.

The observations and interviews that formed the basis of the analysis were conducted during repeated visits between January and June 2017 in Cali-Colombia. Other additional impacts in the supply chain of the women's leather dress footwear were obtained from a literature review of journal articles reporting upon environmental issues in the sector.

*ii. Definition of scope of the system:* The unit of analysis was the production process of a pair of women's leather dress footwear manufactured by small businesses in Colombia. The limits of the system for the analysis of the NEI were defined based on the LCA. The LCA approach was selected taking into account that the environmental evaluation of a product is required not only during the production process but throughout all stages of the life cycle, from the production of components and raw materials to the elimination of the product once it is discarded (Muniozguren-Colindres and Mínguez-Gabiña 2005).

*iii. Negative environmental impacts: Analysis of information:* The NEI were classified according to the MET (material, energy, toxicity) matrix (Brezet and van Hemel 1997), which is a tool that can be used for qualitative LCA (Muniozguren-Colindres and Mínguez-Gabiña 2005) and to determine the inputs and outputs at each stage of the life cycle (Romero-Rodríguez 2003; García 2008; Knight and Jenkins 2009). The purpose of the MET is to identify and classify the most important environmental problems during the life cycle of a product, and the

results can be used to establish improvement strategies (Brezet and van Hemel 1997). The MET matrix is suitable for a preliminary analysis of the system, and it is recommended for eco-design (Knight and Jenkins 2009), especially when there are missing or low-quality data about certain processes and materials of a given product (Vezzoli and Manzini 2008), as is the case with women's leather dress footwear in Colombia. Missing data limits more robust analyses, such as LCA, that attempt to identify, quantify and characterize the different potential environmental impacts associated with each stage of a product's life cycle (Levy 2017).

*iv. Proposal to improve environmental performance:* The information gathered from the previous stages was compared with information reported by journal articles and other documents regarding the NEI. This information was obtained through a systematized information search using three Boolean operators (AND, OR, and NOT). Predefined search criteria, information sources and keywords are detailed as follows:

1. Search criteria: Reports, documents and scientific publications about the sustainability of the footwear sector.
2. Sources of information: publications and reports from researchers and institutions that work on the sustainability of footwear, scientific databases and the Google search engine.
3. Keywords: footwear, sustainability, cleaner production, LCA, inputs, production, materials, waste reduction.

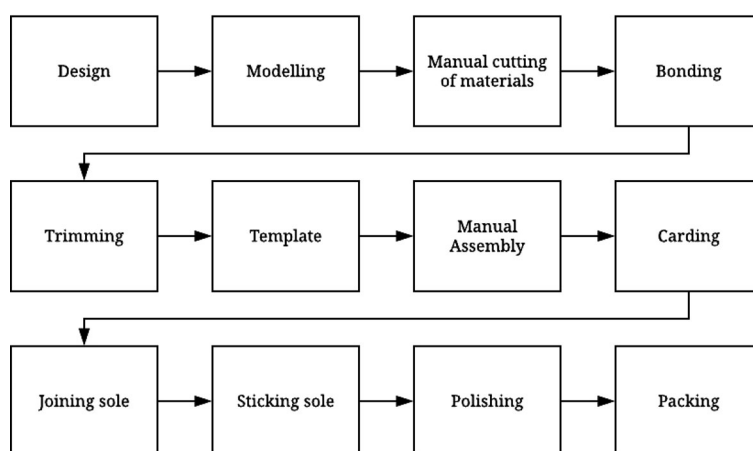
## Results

### *Negative environmental impacts: Gathering information*

Observation in situ and through videos provided meaningful information regarding the detailed characteristics of each stage of the process. The production process varies according to the manufacturer's business model, scale, machinery, and available materials. In the case of the analyzed companies, the process is artisanal, labor intensive and employs little machinery and equipment. The stages of the process are represented in Figure 2.

Throughout the process, there is evidence of low use of personal protection elements, such as gloves, dust and chemical residue masks, and ear covers, and widespread use of inadequate and nonergonomic work surfaces. Parts and materials of a pair of women's leather dress footwear are defined according to the design, e.g. leather, rubber, textiles, and ethylene vinyl acetate (EVA) (Figure 3).

The *design* stage is the least harmful because pencil and paper are used; computers are also used to search for designs, which generates energy consumption. Making the patterns requires paper, masking tape and pencils; however, some companies subcontract the scaling of patterns that can be made in paper or cardboard, which would lead to NEI



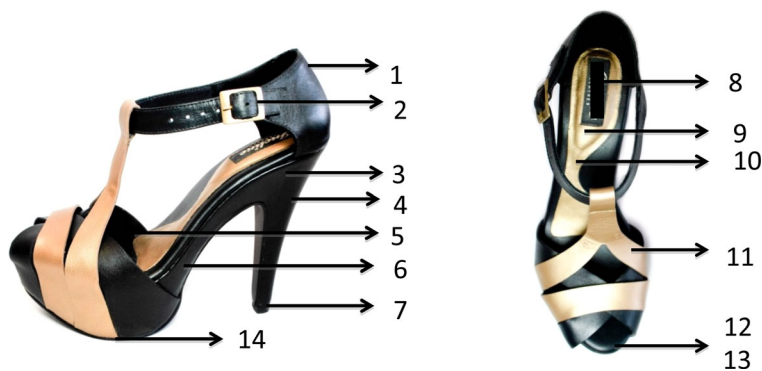
**Figure 2**  
Women's leather dress footwear  
production process.

associated with transportation, the consumption of raw materials and the energy consumption associated with computer-aided design.

In *production* during *manual cutting*, blade residues and mainly leather cuttings are generated because cutting in the direction of the fiber is necessary to avoid tears, and the cutter must be able to cut uneven and imperfect skin to produce patterns of different sizes. An alternative to manual cutting is laser cutting or pneumatic cutting, which is usually subcontracted due to the costs of purchasing and operating the equipment.

Afterwards, pieces of leather and lining are joined in the *bonding* stage. These are readied in the previous stage and are trimmed to thin the leather and achieve folds or parts of pieces with the desired thickness, thus generating leather cuts and the consumption of electrical energy by the roughing machine. Adhesives are used, and noise is generated by the pressure exerted with a hammer on the material to ensure adherence. During *trimming* stage, a sewing or similar machine is used to sew the required seams, and low- and high-adhesion adhesives can be used; this process consumes energy, and there is noise from the sewing machine and from hammering the material on a rigid surface.

After that the material of the template is cut out and adhered with glue to the lining (leather or textile belts), thereby generating cutouts of lining material and insoles, in addition to volatile glue emissions. Seams are also made in the recess around the template to secure the lining, and this can generate noise when the upper sole and the pieces are pressed together with a hammer. Next the template, the upper sole and the platform or heel are fixed in the design with the use of glue in the *manual assembly* stage. Noise can be generated by the use of a mounting clamp and nails to fix the pieces in the design, and cleaners and activators are used, generating residues of rags, brushes and chemical product containers.

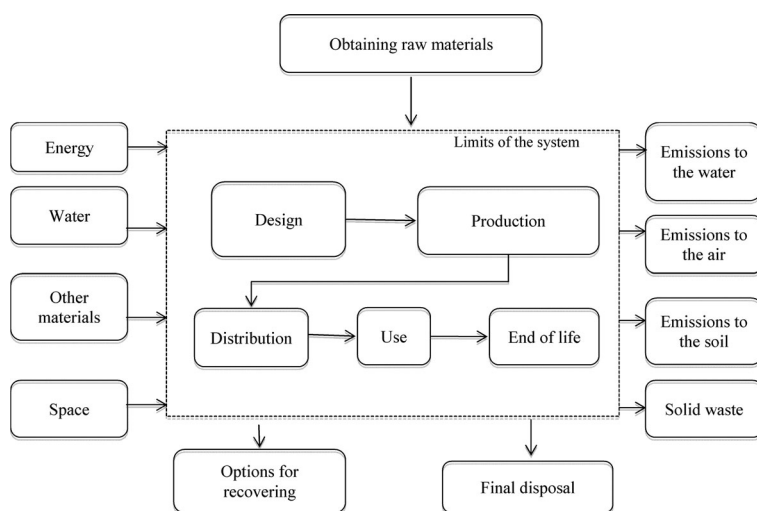


**Figure 3**  
Parts and materials of a pair of women's dress footwear. 1: Butress, imperfil. 2: buckle, metal (Steel-brass-zamac). 3: Platform lining, iron or jute. 4: heel, polystyrene. 5: cap lining, leather chamois. 6: Platform, polystyrene. 7: top, rubber. 8: markings: textile. 9: shock absorber in the heel: foam. 10: cover, leather. 11: upper sole: leather. 12: insole, Celfil. 13: template lining, leather chamois. 14: sole, rubber.

Successively, leather waste and dust are generated by pressing the support points in the mounting with an emery to polish the surface, thus generating noise and power consumption, in a stage known as *carding*. In the *joining sole* stage, the soles are cut, generating cuts of rubber or other materials. Later during the *sticking of the sole*, cleaners, activators, and adhesives are used, and noise is generated by pressure or blows applied to join the materials. During *polishing*, inks and chemical cleaners are used, generating volatile emissions and residue from rags.

Regarding waste from the production process, the analyzed companies lack solid waste management practices, limiting them to separating the cardboard, reusing boxes or plastic bags and, in some cases, separating scraps of leather that they sell to the saddlery sector. Other waste is delivered to the waste collection truck for final disposal as ordinary waste; this includes small cuts of leather and templates, in addition to residues of the oil used in the machines and the containers of cleaners, activators, inks and glue.

During *distribution and sale*, it is common for wholesale customers to collect products from the manufacturer's workshop, but in some cases, transporters are used. The transport supposes NEI because of the atmospheric emissions, the noise and pollution associated with its maintenance and replacement of parts. The transport can affect the footwear quality if several pairs are packed in a cardboard box or protected by plastic bags or cardboard boxes of low grammage. Once the product reaches the wholesale customers, packaging waste is generated, and the product is displayed in the store, generating high energy consumption from lighting and air conditioning for the shop floor. When the footwear reaches the final consumer, waste is generated from plastic bags, packaging, filler paper, labels, invoices and/or any printed advertising included. During *use*, bitumens and products are used for leather moistening and cleaning, and the replacement of heel lids and soles is common. At the *end of life*, footwear usually becomes waste, which is disposed of by homes as ordinary waste in landfills because in



**Figure 4**  
Limits of the system:  
stages considered.

Colombia, they are not recycled, nor are there post-consumption policies for their adequate disposal, despite the possibility of recycling many of their parts and the high volume of units sold. In landfills, due to the degradation of organic matter, microbial metabolism, rainfall, and groundwater intrusion, leachate is generated, and it is often not contained, diverted, collected, or treated (Ye et al. 2019).

*Definition of scope of the system:* The included stages range from design to the end of use, and excluded leather production and solid waste management because they are beyond the aim of this research (Figure 4).

### **Negative environmental impacts: Analysis of information**

The information gathered from NEI on the stages of the supply chain was classified according to categories such as use of materials (M), energy (E), and toxic emissions (T) derived from atmospheric emissions and solid waste, as shown in Table 2. It is worth noting that the production stage is characterized by the intensive consumption of resources. Energy consumption (Pacheco-Blanco, Collado-Ruiz, and Capuz-Rizo 2015) and the use of materials from which waste is generated (Cheah et al. 2013) are significant in the analysis. Energy consumption is mainly due to the use of machinery and tools in different stages of the process. The use of materials such as leather, rubber and others necessarily produce waste that is sent to the landfill regardless of the option to recover value from the waste. It is important to stress that the analyses provided by the MET matrix are qualitative; therefore, quantities for energy use, the use of materials and waste generation are beyond the scope of the qualitative LCA.

Table 2. MET matrix for women’s leather dress footwear.

Stages of life cycle	Subprocess	Use of materials (M)	Electric energy (E)	Toxic emissions (T)			Observations
				Water use	Atmospheric emissions	Solid waste	
Production	Design	Paper, pencil, colors	Electricity for computer	-	-	Paper, waste of pencils, colors and markers	-
	Modeling	Pencils, poster board, cardboard, tape, compass, eraser, rulers, blades	-	-	-	Poster board, cardboard, pencils, colors, eraser waste	-
	Manual cutting of material	Leather, chamois, lining,	-	-	-	Blade, leather and pad, buttress waste, Celfil, Celtec and Evalatex residues	-
		Buttress, Celfil, Celtec, Evalatex, blades					
	Bonding	Leather, drying oven, glue, hammer, ink, grinding machine	Electricity for the drying oven and the grinding machine	-	Adhesive particles and organic volatile components	-	Considerable hearing pollution: due to hammering
	Trimming	Thread, buttress, glue, buckle, hammer, post and grinding machine	Electricity for post and grinding machine	Brush washing	Adhesive particles and organic volatile components	-	Moderate hearing pollution: due to hammering and post and grinding machines

(Continued)

Table 2. (Continued).

Stages of life cycle	Subprocess	Use of materials (M)	Electric energy (E)	Toxic emissions (T)		
				Water use	Atmospheric emissions	Solid waste
Distribution and sales	Template	Hammer, scissors, Celfil, Evalatex, glue, brush, labels	-	Brush washing	Adhesive particles and organic volatile components	Cuts of ethylene vinyl acetate (EVA)
	Manual assembly	Clamp, hammer, tacks, glue, brush,	Electricity from oven for adhesive activation	Brush washing	Adhesive particles and organic volatile components	-
	Carding	Blade, emery	Electricity for the emery	-	-	Cuts of leather; powder
	Joining sole	Knife	-	-	-	Cuts of rubber
	Sticking sole	Glue, brush, drying oven, hammer, sizes	Electricity for the drying oven	Brush washing	Adhesive particles and organic volatile components	-
	Polishing	Cleaner, ink, applicator, rags, brush	-	-	organic volatile components	Rags, brush
	Packing	Boxes, paper, stickers	-	-	organic volatile components	-
	Distribution of finished product, transportation	Vehicle	Electricity in the storage processes and electronic equipment	-	Generation of atmospheric emissions due to fuel consumption	-
	Sale to final customer	Store	Electricity for the lighting and air	Water for cleaning and	-	Waste from packing

(Continued)

Table 2. (Continued).

Stages of life cycle	Subprocess	Use of materials (M)	Electric energy (E) conditioning of the store	Toxic emissions (T)		
				Water use bathrooms in the store	Atmospheric emissions	Solid waste
Use	Unpacking	-	-	-	-	Waste from the box
				-	-	and paper
End of useful life	Cleaning	-	-	-	-	Packaging of cleaning products
	Scraps	-	-	-	-	Leather
						Template in organic material.
						Plastic platform
						Rubber outsole

Note. Source: Matrix modified based on Brezet and van Hemel (1997)

**Table 3.** Common waste management practices and actions required in the companies analyzed.

Waste or scrap	% Recycling/ handling in workshops	Waste management	Final disposal	Required actions
Cutouts of paper, cardboard, poster board	100	Separation	Delivery to recycler for sale	
Cut of leather	100	Production of labels, key rings and small leather goods	Poor leather or small cuts go to the collection truck	Find recycler or other uses of the material
Cutouts of Celfil, Celtec and Evalatex (left over from template)	0		Waste truck	Find recycler or other uses to the material
Cuts from soles (rubber)	0		Waste truck	Find recycler or other uses to the material
Cardboard boxes	100	Separation	Delivery to recycler for sale	None
Plastic containers, glass	0		Waste truck	Labeling and handling of hazardous waste
Plastic bags	70	Package of cuts of leather and waste bag	Waste truck	Find recycler or other uses for the material
Atmospheric emissions from glue	0			Filter in extraction system
Rags and brushes	0			Labeling and handling of hazardous waste
Luminaires	0			Delivery to producer for proper disposal

### ***Proposal to improve environmental performance***

This section was developed based on the results of the MET matrix and a literature review, as well as on the actions in which companies engaged while performing their activities. Tables 3 and 4 summarize the proposals to improve environmental performance based on the above-mentioned results. For example, during the *design* stage, it is important to consider the proposal of Politowicz (2013) and select materials that do not pose a risk to the consumer during use (Herva, Álvarez, and Roca 2011) and that ensure products of adequate durability and quality (Laitala, Boks, and Klepp 2015). During this process, initiatives such as Nike's MAKING app can be useful to compare the impacts of materials; the tool was designed to inspire designers and creators to make better choices regarding the materials they use (Zhao and Balagué 2015).

**Table 4.** Proposed actions to reduce the environmental impact generated in the female LCF.

Stage of supply chain	Improvement strategies	Types of associated measures
Design	Promote eco-design	Promote timeless design and eco-design. Optimize pattern and make constructive and usability tests. Generate final pattern scaled from original pattern with computer-aided design programs. Prioritize recyclable and low NEI materials
Production operations	Select environmentally efficient production techniques	Apply principles of lean manufacturing. Apply cleaner production Reduce the use of materials Optimize the quality and durability of the products Promote of craft processes and manuals Reduce the consumption of energy, water and solid waste generated Reduce the stages of production Properly manage waste Encourage the use of indicators to evaluate the consumption of resources Maintenance of equipment to reduce energy consumption Isolate equipment and surfaces to reduce noise
Distribution and sale	Select ways to engage in environmentally efficient distribution and sales	Reduce packaging and boxes. Substitute raw materials for less polluting materials in smaller quantities and reusable Select of energy efficient transport mode Engage in proper waste management in store. Reduce energy consumption in signage and lighting in stores Reduce the weight and size of packaging.
Use	Promote proper maintenance and responsible consumption	Inform clients about maintenance and repair Facilitate maintenance and repair of products
End of useful life	Promote reverse logistics	Promote responsible consumption Promote the reuse of the product Modernize or reprocess footwear Recycle of materials

Besides, the type of materials that comprise the product, their diversity and the feasibility of recycling them after the end of life must be defined as in Staikos and Rahimifard (2007a, 2007b). The *design* should be timeless, avoiding excessively fleeting fashion trends and ensuring that the aesthetic life of the product is not shorter than the technique. Additionally, companies should minimize the waste of materials

generated in design, prioritizing patterns with small parts and performing constructive and usability tests (INESCOP 2009). Likewise, the scaling of patterns with computer-aided design is recommended to avoid errors in the scaled pieces.

In *production*, NEI is mainly associated with energy consumption and waste generation; therefore, it is recommended that cleaner production be applied and LCA performed to assess the NEI and all intervention in each stage of the LCF. Likewise, it is recommended that lean manufacturing be employed to reduce materials waste and energy consumption (Theagarajan and Manohar 2015; Caldera, Desha, and Dawes 2017). According to INESCOP (2009), it is also recommended that manufacturers (i) choose processes that optimize the use of materials, e.g. computer-controlled leather cutting machines that optimize cutting and generate less waste; (ii) raise awareness among workers to reduce energy consumption in production; (iii) design footwear seeking to minimize the waste of materials; and (iv) try to recycle surplus production within the company itself. However, computerized cutting machines are not recommended for small businesses without a cost-benefit analysis due to the high costs of acquisition, operation and energy consumption and because manual cutting is efficient and inexpensive in companies that generate few units. To optimize the use of energy, it is recommended that a heat gun be used to activate adhesives with temperature rather than resistance furnaces. Likewise, low energy consumption should be a criterion for the acquisition of machinery and equipment, and a maintenance program should be designed.

Regarding waste from the production process, the cutting stage of the outsole, insole and reinforcement generates approximately 25–35% of total waste, which represents 80 tons of waste/million pairs (UNIDO 2000). “The ethylene vinyl acetate EVA represents 14% of this waste. Therefore, 190,400 tons of EVA waste are generating worldwide every year requiring a large surface for placement and storage and generates great costs of management due to its long biodegradation period” (Lima, Leite, and Santiago 2010).

Alternatives for reuse, creation of byproducts or sale can be considered to reduce waste generation and promote recovery; e.g. purses, bracelets, and key rings are made with leftover foam and leather. The materials that cannot be reused in the company can be sold or donated to saddlers or artisans, so the waste must be separated correctly to avoid pollution. It must be a priority to identify and properly manage hazardous waste, such as glue containers, cleaners, oils and other substances. According to Colombian legislation (decree 4741, 2005), empty containers that hold the raw materials of adhesives, dyes, oils, and solvents or the impregnated residues of these substances are classified as hazardous waste. In addition, it is recommended that fluorescent tubes containing heavy metals and printer cartridges be separated and recycled, dates tracked for when storage of hazardous waste begins and final disposal

conducted within a period of six months (Gomez and Vazquez 2009). Flammable raw materials must have a safety sheet, and their storage conditions must be verified according to the manufacturer's specifications; these actions were not usually performed in the companies analyzed. Additionally, firms should consider procedures for action in case of spills, specifying the collection method and the final disposal of the waste generated.

Noise can be reduced in *production* by installing shock absorbers in the supports and insulation of machinery, equipment and work surfaces. Likewise, the facilities should be equipped with water-saving faucets and toilets and translucent tiles that favor natural lighting, as in the case reported by Londoño-Benitez (2010).

In the *sale* to wholesalers, production on request should be considered, and for the sale to the final customer, sales forecasts should be developed to reduce losses of raw material due to surpluses and inventory deterioration. Priority should be given to durability, quality, and style using artisanal processes that demand less energy consumption and favor the generation of qualified employment, as occurs with luxury brands (Joy et al. 2012).

It has been reported that NEI is not relevant in the *distribution* stage compared to the operations involved in production and end of use (Pacheco-Blanco, Collado-Ruiz, and Capuz-Rizo 2015). Nevertheless, commercial agreements must be made with merchandise transport providers who are leaders in environmental aspects and ideally have ISO 14000 certifications. These agreements would reduce NEI because these companies optimize their routes, fuel consumption and properly manage their waste. It is desirable that footwear be distributed in recyclable and reusable cardboard boxes and in packaging with smaller volume and weight, which enable the transport and conservation of footwear (INESCOP 2009). Ideally, companies could handle at least three sizes of boxes (sizes 35–36, 37–38, and 39–40) to achieve efficiencies in transportation; however, depending on the nature and scale of the business, the investment might not be justified. The reduction in the NEI associated with packaging and transportation is of interest to the footwear industry, e.g. the redesign of Sketchers packaging (Roldán-Vélez and Ruiz-Arenas 2009).

The use, maintenance and repair of footwear must be reported during the *use* stage through different channels of communication with customers to focus on responsible consumption. At the end of life, the reuse of footwear should be encouraged through donation when it is in good condition. Additionally, footwear to be discarded might be biodegradable; therefore, the materials used in production must be chosen to accomplishing this constraint and with low NEI, as proposed by Albelda-Reyes et al. (2011); Albers, Canepa, and Miller (2008); and Pacheco-Blanco et al. (2010).

Another way of improving the management of the footwear at the use and end of life stages is to look at the flow of materials in the supply chain and to shift from a linear model of production and consumption to a circular model according to the National Policy in Solid Waste Management for Colombia (Consejo Nacional de Política Económica y Social and Departamento Nacional de Planeación 2016). This policy is based on a circular economy, which aims to keep the materials in the production loop longer to avoid carrying materials to the landfill. Additionally, this policy attempts to achieve sustainable development goals such as responsible production and consumption and sustainable cities and communities. Examples of this type of management are reported in the fashion value chains (Bocken et al. 2016) for reducing the amount of resources (material and energy) used during the design, manufacture, distribution, use and disposal of products (Bocken et al. 2016) and extending the life cycle, thereby reducing the overall demand for the product and closing the cycle of materials, including recovery activities (Pal and Gander 2018).

Reverse logistics (RL) is a highly recommended strategy; RL is the process of planning, implementing and controlling an efficient and cost-effective flow of raw material, inventory in process, finished product and information related to manufacturing, distribution or use with the purpose of recapturing value or appropriate disposal (Dekker et al. 2004). RL can be implemented in footwear companies that control production and marketing, as reported by Silveira Guimarães and Salomon (2015). It is viable to close the life cycle by implementing campaigns encouraging consumers to return footwear to the store when it has completed its life cycle, thereby recovering materials and correctly managing the disposal options.

Extended producer responsibility programs are being adopted in textile companies through the recovery of the value of the products they manufacture when they end their life cycle in the hands of the consumer (Hvass 2014). However, in the fashion sector, there is a lack of studies that explore the limits of the reuse and recycling of textiles and other materials or the benefits of combining their different types and routes (Sandin and Peters 2018).

## Discussion

Despite the advances and interest of the fashion industry in being more sustainable, the evidence in the Colombian case shows that the production and sale of women's leather dress footwear by small and medium businesses entails a series of NEI mainly associated with the use of polluting raw materials, generation of waste, energy consumption, and unfavorable working conditions for employees. These NEIs are caused by the unsustainable landscape of the fashion industry and require alternative solutions, new business models or a rethinking of entire systems (Dissanayake and Sinha 2015). The latter must take into account that

people consume more natural resources and produce more pollution than the planet can sustain and that businesses must operate within the planetary boundaries and the ecological carrying capacity of the planet (Joy et al. 2012).

There is a consensus that in the fashion industry, business models can be seen as agents of sustainable change (Pal and Gander 2018), but for this approach to materialize in the footwear industry, it is important to guide decisions by making an important distinction between the strong and weak approaches to sustainability (Quintero-Angel et al. 2018). The strong sustainability approach places environmental value at the heart of the operation, making it the driving logic and most important performance metric (Pal and Gander 2018). While strong sustainability highlights the importance of harmony between nature and economic growth, weak sustainability justifies the use and damage of nature to obtain economic growth and does not involve a radical transformation in businesses (Munda 1997).

For the Colombian case, the fashion industry must develop business models that compete on quality and differentiation and not on price. It is necessary to develop companies and brands that address social responsibility and environmental aspects, such as compliance with the national policy of solid waste for the circular economy, not only to meet the national demand but also to compete internationally due to their high design component and added value (McKinsey & Company 2009). However, regarding the women's leather dress footwear producers, current reality must be addressed, and producers who have not had sustainability as a priority should go from weak to strong approaches of sustainability to implement the strategies proposed (Table 4).

One of the greatest problems common to many companies in the footwear industry in Colombia is a lack of modernization and technical knowledge (Ministerio de Comercio Industria y Turismo 2012), which is why the sector should be supported in its transformation process. Furthermore, a major challenge will be to verify the presence of toxic elements in raw materials and take a critical position relative to the adoption of either weak or strong sustainability approaches.

Currently, a limitation to reducing the NEI in this sector in developing countries such as Colombia, is the low attention for sustainable materials from the members of the supply chain leading to the limited development and availability of these materials (recycled or biodegradable) for platforms, soles and other supplies. Additionally, access to certified tanneries (ISO 14000) in Colombia in early 2019 is limited to one company, which restricts the range of leather colors for the design process and increases the risk associated with depending on a single supplier.

In small businesses manufacturing women's leather dress footwear, the creative process should be guided by eco-design, a perspective that

considers the environment as another factor to be considered in decision-making to generate less harmful products (Muniozguren-Colindres and Mínguez-Gabiña 2005). An eco-designed product has a similar or superior quality to its equivalent in the market, with the added value of being an innovative product that is more respectful of the environment (Albelda-Reyes et al. 2011). Eco-design represents the design or redesign of what currently exists with environmental considerations, but by itself, it is not sufficient to represent a true sustainable solution (García 2008; Romero-Rodríguez 2003), since companies should question unsustainable business models such as fast fashion (López-Barrios 2012). However, eco-design is an interesting approach to environmental problems, and it can generate important results for sustainable businesses.

Likewise, in their manufacturing processes, these companies should prioritize cleaner production, perform LCA to assess the NEI, and intervene in each stage of the LCF. Likewise, it is recommended that they employ lean manufacturing and engage in the circular economy or “looped” approach to the study of fashion value chains (Bocken et al. 2016). These approaches will benefit both researchers and manufacturers in gaining valuable information on the influence of these practices on corporate environmental sustainability, in meeting the demands of sustainable development goals, and in providing new paradigms and pathways to achieve a balance between nature and economic growth in business practice (Caldera, Desha, and Dawes 2017).

It is also required that ethical sourcing and social value creation be promoted by creating ethical consumption campaigns for footwear. “This positioning attempts to counter the otherwise hectic speed of consumer behavior by giving structure and meaning to fashion product that can lead to a more deliberate, selective and slower style of purchasing and use” (Pal and Gander 2018, 255).

In developing countries such as Colombia, footwear manufacturers are not required to have environmental permits, so they are not required to form business environmental management departments. However, this study agrees with Gomez and Vazquez (2009) about the need to have detailed studies concerning the NEI of footwear because of the cumulative effect that companies in the sector could generate (Talbot, Lefebvre, and Lefebvre 2007). Likewise, it is recommended that manufacturers voluntarily establish environmental management departments to take steps to reduce their NEI and develop environmental indicators regarding the consumption of materials and energy (Table 4).

Finally, the university-company-state relationship could support environmental actions in the sector to improve corporate sustainability performance, e.g. conducting research and development and finding alternatives for the recovery of materials, as was done for the recycling of cuts of EVA from templates in the manufacture of light concrete (Lima, Leite, and Santiago 2010) and the development of natural and

synthetic compounds for sustainable application in the footwear sector (Lopes et al. 2015). Moreover, industrial symbiosis could be developed from industrial ecology (von Hauff and Wilderer 2008), as was the case with rubber in Malaysia (Sharib and Halog 2017).

## Conclusions

While at the global level, there are interesting advances in the fashion industry and in footwear production to reduce the NEI, the advances are still disparate and in many cases still emerging. The evidence in the Colombian case shows that the production and sale of women's leather dress footwear by small and medium businesses has received insufficient attention from both academic scholars and practitioners, and there remain significant challenges to complying with environmental and labor regulations and to developing sustainable businesses that find a differentiating value in terms of design and artisanal processes.

The Colombian case shows that the NEIs of leather dress footwear are concentrated in the production stage, mainly due to energy consumption (sewing machine, trimmers and furnace) and the generation and inadequate disposal of waste, especially during manual cutting, stenciling and carding. Furthermore, due to the use of glue, activators and chemical cleaners in the manufacturing process and the inadequate disposal of waste from rags, the process generates brushes and containers of chemical products.

In view of the identified NEIs, adjustments are required to the supply chain and in the methods by which products are manufactured, purchased, used, and disposed of, especially in consumption, because a well-informed consumer decision about the footwear purchased and lower consumption would reduce the demand and the NEI. Likewise, it is required that the environmental authorities conduct detailed studies on the NEIs of the sector because environmental permits should be required from manufacturers, and/or environmental management departments should be established that reduce the NEI and implement the proposed strategies (Table 4).

To reduce the NEI and improve the environmental performance of the sector, eco-design tools and methods such as lean manufacturing, cleaner production, the circular economy and LCF must be applied. At the end of its useful life, the reuse, modernization or reprocessing of footwear and the recycling of materials should be encouraged; RL could be useful. The current situation also requires the greater integration of producers, suppliers, distributors, recyclers, environmental authorities, etc., in addition to greater investment in research and development, to generate sustainable raw materials that are currently difficult to acquire, thereby reducing competitiveness in the world market.

Finally, it is desirable for the proposed NEI reduction actions be incorporated into business decision-making. However, to achieve sustainability in the footwear sector, one must question unsustainable

business models, such as fast fashion, exaggerated consumption and the global supply chain, and develop more detailed studies about the NEI in the LCF. In this study, the MET matrix contributed to the identification of the NEI, but this tool's qualitative character limits the scope of the analysis.

### Disclosure Statement

No potential conflict of interest was reported by the authors.

### Note

1. Since these videos are publicly available, the company names may appear in this text. All individuals and companies who were directly visited or interviewed for this study remain anonymous.

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