Design for Sustainability in the Footwear Sector: Survey on Strategies and Impacts Mitigation

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Abstract. The environmental costs related to the production processes, the exposure of workers to inadequate conditions, the high competitiveness and the accelerated growth of the footwear sector, are results of the current production and consumption model, which also reverberates on the premature disposal of footwear and the lack of management of waste from its production process. Given these facts, this article seeks to understand which Design for Sustainability (DfS) approaches are being implemented in the sector. Through a literature review, the most used DfS approaches were identified and with a desktop research, a survey on examples was carried out, in order to mitigate the impacts through the concepts of Circular and Distributed Economy, models can enable greater resilience for small businesses in the sector, through local production and consumption. 16 examples of companies in the footwear sector were selected and analyzed, the study made it possible to carry out a critical analysis regarding the use of isolated strategies and a reflection on the incorporation of different DfS approaches. In addition, the study provides a wide repertoire of solutions and good practices for other designers in the sector.

Keywords: Shoes, Circular Economy, Distributed Economy, Design for Sustainability.

1 Introduction

The footwear industry is responsible for several impacts on the environmental, social and economic dimensions of sustainability (UNECE 2018). The toxicity of materials and production processes; the difficulty in end-of-life solutions; the consumption of water and energy in the manufacture of raw materials and the exposure of workers to inadequate working conditions are the main impacts observed (Jacques and Guimarães 2011; Dominique Muller and Paluszek 2017; Ashton 2018; Guarienti et al. 2018).

The accelerated growth of the sector causes repercussions on the life cycle reduction of shoes, leading to the absence of solutions for managing the waste resulting from the production process and the premature disposal of products (Vezzoli et al. 2022). It is estimated that the sector annually generates 2.6 million tons of waste and

that 91 million pairs of shoes that are not sold as a result of overproduction are incinerated annually worldwide (Kohan et al. 2020). The accelerated pace of this production model generates strong price competition between brands and manufacturers, resulting in significant impacts on the economic dimension (Boër et al. 2007; World Footwear 2022). In addition, there are violations of labor rights and a lack of transparency and traceability in the footwear value chain, compromising the sustainable development of the sector (UNECE 2018).

The footwear production usually occurs far from the places of sale, making it difficult for consumers to perceive the working conditions involved in the process and the exploitation of natural resources (CAVALCANTE 2020). In addition, the sector depends on a vast range of inputs and resources, which makes its value chain wide and complex (Silva et al. 2015).

Given these facts, Design for Sustainability (DfS) provides a series of strategies to think new configurations of the production and consumption model in the sector, implementing sustainability through systemic thinking (Rinaldi et al. 2022). In this way, this article seeks to contribute to the mitigation of the impacts caused by the sector through a literature review and a survey on examples, in order to identify design strategies oriented to Circular and Distributed Economy, concepts that can enable significant resilience of business through local production and consumption.

1.1 Main Impacts and Challenges for Sustainability in the Footwear Sector

Given the wide variety of models and styles of shoes on the market, the production processes are multiple (Rathinamoorthy and Kiruba 2020). A range of components made of different materials such as leather, rubber, plastics, fabrics and wood are required for its manufacture (Dominique Muller and Paluszek 2017). Footwear is a complex product and its structure comprises the junction of these materials, which are sewn or joined by adhesives so that the parts do not disconnect, this process makes reuse and recycling processes difficult (PASSOS 2014; Guarienti et al. 2018).

The life cycle of a product is made up of a set of activities and processes that consume resources and energy and generate emissions of various types throughout the pre-production, production, distribution, use and disposal phases (Vezzoli and Manzini 2008). The lifespan of a shoe is usually short and gradually shortens due to rapid changes in fashion trends and the consumer market (Morlet et al. 2019). Changing these practices is a complex challenge, which ranges from the formulation of problem-oriented public policies to consumer education (Vezzoli et al. 2014).

In the environmental dimension of sustainability, the consequences observed by the practices of footwear production chain are diverse: the Emission of Greenhouse Gases; Land use (habitat change, deforestation, urban development, agriculture, waste); Release of toxic chemicals; Depletion of water resources; Climate change (global warming); Depletion of the Ozone layer and effects on aquatic organisms due to toxicity and the formation of particles (microplastics) dispersed in rivers and oceans (Kim et al. 2022; Vezzoli et al. 2022).

In the social dimension, there are violations of human and labor rights caused by the lack of traceability and transparency in the production chain and social, racial and gender inequalities (Dominique Muller and Paluszek 2017; UNECE 2018; Fashion Revolution Foundation 2021; Vezzoli et al. 2022).

The economic dimension has the effect of barriers caused by patents and intellectual properties of large companies that affect small producers, and the great price competitiveness that leads to outsourcing (Boër et al. 2007; Santos et al. 2021; Scherer et al. 2021).

1.2 Design for Sustainability Contributions in the Footwear Sector

The most recent Design for Sustainability (DfS) approaches have more emphasis on socio-environmental issues, with strategies centered on people, collaborative, shared processes and communities (Gwilt 2020; Macêdo et al. 2022).

As described by Ceschin and Gaziulusoy (2020), the approaches are named: (i) Emotionally Durable Design: strengthens the user's bond and seeks to avoid premature disposal of the product; (ii) Design for Sustainable Behavior: makes people adopt a desired sustainable behavior; (iii) Design for the Base of the Pyramid: develops solutions to meet the needs of low-income people; (iv) Design for Social Innovation: design, development, promotion and expansion of social innovations; (v) Systemic Design: designs locally-based production systems where waste from a production process becomes inputs for other processes; and (vi) Design for Sustainable Transitions: seeks an expanded holistic view and focuses on transforming socio-technical systems through technological, social, organizational and institutional innovations.

The authors propose a theoretical model with these approaches distributed in 6 levels of innovation: (i) Material: interventions to gradually improve products, developing new materials or replacing them; (ii) Product: seeks to improve existing products or develop new ones, considering the entire life cycle; (iii) Product-Service System: these are integrated combinations of products, services, stakeholder value chains and business models; (vi) Space-Social: deals with the space-social conditions of communities, from neighborhoods to cities; (v) Socio-Technical Systems: design interventions that focus on promoting radical changes in the way society's needs are met; and (vi) Socio-Technical-Ecological Systems: focuses on systems in their entirety and envisions the field becoming Earth-centric, on all forms of life and on future generations.

According to Vezzoli et al. (2022), design intervention should not be limited only to the material level. To solve the complex problems of the product value chain, it is necessary to think about approaches and strategies located at the highest levels, as these are potentially more sustainable.

Gwilt (2020) presents a model to guide fashion designers in choosing the most appropriate strategies according to the phases of the product's life cycle, which can be multiple, represented by the term Design for X (DpX). In the pre-development phase, the model suggests Design for empathy, low impact of materials and processes and for the use of mono-materials. At the production stage, Design for zero waste, longevity, efficient use of materials and resources, fair trade and production. In the Distribu-

tion phase, the strategies are Design for need, to minimize transport, reduce or reuse packaging and to engage local communities. The use phase presents Design strategies for multi-function, modularity, low-impact, customization, repair, and product-service systems. In the last phase, at the end of the product's life cycle, the model recommends Design strategies for reuse, disassembly, recycling and upcycling, remanufacturing and closed-loop systems.

According to Dwivedi et al. (2022); Fashion Revolution Foundation (2021); Koszewska (2018); Santos (2008) and Unece (2018) the most discussed strategies in the footwear sector today are: (i) Efficient assembly and disassembly; (ii) Appropriate selection of materials and service providers; (iii) Development of DfS-oriented skills and competences of artisans; (iv) Consumer involvement in the processes of the footwear value chain, design and manufacturing; (v) Extension of the product's life cycle and (vi) Creation of product-service systems.

1.3 Mitigation of Impacts on the Footwear Sector through Circular and Distributed Economy

The Circular Economy (CE) concept is widely discussed in the footwear sector (Blume Vier et al. 2021). It is a regenerative industrial system that replaces product disposal with restoration and has as its main objective the elimination of waste through design (Ellen Macarthur Foundation 2013). Valtonen e Nikkinen (2022) believe that the industry is in transition to CE, which requires the skill of designers to develop products that can be used longer, repaired or recycled. However, the main challenges for implementing recycling processes in the footwear sector are technical barriers such as the lack of product separation technologies and mixed materials, logistics, and changes in consumer habits (MODEFICA, FGVces 2021).

Strategies such as Design for the environment; modularity; recycling; reuse; disassembly; maintenance; product integrity; and for the end of life, are examples that enable circularity in the footwear sector. Although they help to contain the negative environmental effects of the sector, they are influenced by the strong trend of downcycling, where there is a degradation in the quality of recovered materials that are normally reused in economic processes with low added value (Fletcher and Grose 2012; Christensen 2021). It is noteworthy that reuse and recycling do not prevent the production of waste and do not cause deeper changes in consumption habits. According to Fletcher and Grose (2012), it is important to consider that this model can encourage production and consumption, causing a rebound effect and increase the unsustainability of the footwear sector.

To overcome this challenge, it is necessary to balance measures that meet a holistic approach to sustainability to minimize any possible socio-environmental impact (Fletcher and Grose 2012). In this way, the Distributed Economy (DE) appears as an opportunity for a systemic change in the sector. This model promotes the distribution of production to regions where various activities are organized in small units that are synergistically and flexibly connected to each other (Johansson et al. 2005).

According to Vezzoli et al. (2018), the DE concept is locally based and can also be made open to non-local or global systems, associating eco-efficiency with equity and

social cohesion. The proximity between end customers and manufacturing resources such as factories, workshops, personal fabrication labs (model where anyone can manufacture objects using accessible tools), FabLabs, Makerspaces, or mobile manufacturing units makes DE possible the use of participatory design and co-design strategies (Crul and Diehl 2006). This collaboration network can include amateurs, prosumers (consumers who become producers), producers, creative communities, and specialists from different areas (Santos et al. 2021).

The local-global potential of the distributed strategy can humanize production processes and provide an alternative to complex global supply chains. It is a possible solution for excessive consumption, characteristic of centralized mass production, through the use of Open Design, which promotes activities such as Do-it-Yourself (Armstrong et al. 2021). The model also generates new opportunities for use of digital technologies, such as Digital Fabrication. Enabling a fusion of digital and physical technologies, greater flexibility in manufacturing and service delivery, and knowledge sharing among local actors (Vezzoli et al. 2018).

2 Research Method

For a better understanding of the problem and how CE and DE have been explored in the footwear sector, a literature review was carried out. Publications peer reviewed from the last 5 years were selected on sustainability in the footwear sector, as well as the evolution of CE and DE concepts and strategies.

With the support of a desktop research, a survey on examples was carried out to identify and analyze cases related to the DfS approaches that were identified in the literature review. A total of 16 examples were selected and with the support of a table containing the name of the brand, project or company name, the place of origin and a brief description of the activities, it was possible to identify the most used strategies according to the literature review. The most used DfX (eg Design for multifunctional use) were identified and analyzed based on the model proposed by Gwilt (2020), the Ecodesign Guide for the Footwear Industry developed by the Life Green Shoes 4 All project (2020) and the theoretical model by Ceschin and Gaziulusoy (2020).

3 Results and Discussion

From the literature review, the DfS approaches and the DpX strategies most used in the sector were identified. From this data collection, and from the survey on examples, 16 companies that adopt CE and DE oriented strategies were selected and analyzed. The examples selected, their origin and the description of their activities and strategies, are detailed in Table 1.

Among the 16 examples detailed in Table 1, 11 adopted strategies predominantly oriented to the CE concept, while only 5 adopted the DE concept. The selected examples related to CE mostly adopt **Design for Reuse**; **Remanufacturing**; **Recycling**; **Upcycling; Emotional Connection**; **Low Impact of Materials and Processes**; **Longevity**; **Multifunction**; **Efficient use of Materials and Resources**; **Environment**;

Reduce or Reuse Packaging and for **Sustainable Behavior**. In addition, they rely on local artisans and supplier's valorization. On the other hand, cases that are more DE-oriented adopt **Distributed Design** strategies; **Open Design**; **Co-design**; **Digital Manufacturing**; **Product-Service Systems**; **Do-it-Yourself** and **Personal Manufacturing**.

Table 1. Examples of CE and DE strategies in the footwear sector.

Name	Origin	Description
Sujo	**Brazil**	Carry out **customization** and **personalization** of projects in **made-to-order** shoes, also customizes **second-hand** items **and reuses waste** in his creations. **Predominant model: EC**
RE49	**Italy**	The brand works with **waste reuse** from other companies and all its products carry a microship to enable **traceability** and **transparency** of its production chain and product life cycle. **Predominant model: CE**
WAO	**Italy**	The products are manufactured **locally**. The company collect the products at the end of their life and they are 97% **recycled**. **Predominant model: CE**
Marita Moreno	**Portugal**	The production is **local**, valuing the tradition in the manufacture of shoes that are only produced in **limited editions**. The products are made with **reuse** of leftovers from other productions and with **upcycling** techniques and all inputs are locally sourced. **Predominant model: CE**
Senaker Impact	**United States**	The project collects sneakers in different locations and they are sent to separate the parts that are sold to **partners** who do the **remanufacturing** process. It is a source of inputs for manufacturers looking to create products from post-consumer waste. **Predominant model: EC**
Blue View	**United States**	The brand uses **biodegradable** inputs to produce the shoes, the products are **durable** and at the end of their life cycle can be **composted** and works on design concepts for **multifunctional use**. **Predominant model: CE**
Undo for Tomorrow	**Brazil**	They carry out an **appropriate selection of materials**, and inputs are selected to obtain a higher **recycling** rate after the end of the life cycle. They are manufactured **locally** in a family-owned industry. **Predominant model: CE**
Helen Kirlum	**England**	Transforms shoes that would be discarded into new pairs. Each pair developed is unique, and can be **made to order**. Uses **reuse** of materials to manufacture parts. **Predominant model: CE**
Pompeii Brand	**Spain**	100% of the materials used in production are **recycled** or r**ecyclable** and the products are **traceable**. They have full control and **transparency** over the supply and distribution chain, ensuring **good practices** in processes and respect for human rights. In addition, they **control toxic emissions** from products and develop solutions to **reduce** the impact caused by **packaging**. **Predominant model: CE**
ReyRey	**Denmark**	**Capsule collections** are launched only twice a year, so as not to promote excessive production and encourage **conscious consumption**. **Reuses** fabrics and also uses waste from the production to manufacture new products. Suppliers are selected with high criteria focused on environmental responsibility and shoes are designed for **longevity**. **Predominant model: CE**
Filling	**Nether-**	Promotes **transparency** in the processes. Uses materials of natural,

Pieces	**lands**	organic and **compostable** origin, seeks to **reduce the emission of toxic components** and publish a report with the assessment of the **life cycle** of its products, in order to **educate consumers** about conscious consumption. **Predominant model: CE**
Fctry Lab	**United States**	Promotes **distributed design** through the **sharing of resources** from an independent **technology** laboratory dedicated to the creation and prototyping of shoes. It focuses on helping young shoe designers and providing access to resources that are normally held by large corporations. **Predominant model: ED**
Brooklyn Shoe Space	**United States**	For designers and **makers**, it is a **shared space** for shoe manufacturing, offers courses to promote the traditional craft of shoemaking, and produces products for **small local** brands. **Predominant model: DE**
Mercado Granaditas	**Mexico**	The Tepito neighborhood in Mexico City has a tradition of commercial activities, and many of its residents are dedicated to shoe manufacturing. Along the main avenue there are several stores supplying inputs for the manufacture of shoes, and ateliers offering production or **repair** services. Shoemakers share their resources for production and finished products are sold **locally** at the Granaditas Market, considered the largest shoe factory in the world due to the **collectiveness** and **sharing of resources**. **Predominant model: DE**
Sneaker Kit	**Switzerland**	The project provides **Do-it-Yourself** shoe kits for sale online with videos and tutorials for the customers. In addition, they offer several **workshops** for assembling shoes in person with the support of instructors, involving the **consumer in the process and design**. **Predominant model: DE**
The Parachute Collective	**UK**	It is a **shared space** for designers and makers to manufacture shoes, offers courses and enables **personal manufacturing**. **Predominant model: DE**

It is noted that the examples use the strategies and principles of the economic models discussed in this article in isolation, they do not adopt hybrid solutions of CE and DE. As pointed out by Vezzoli et al. (2022) in the literature review, designers should adopt an expanded holistic approach to solve the complex problems of the product value chain.

According to the Brazilian Footwear Industries Association (2022), the main practices carried out by companies in the footwear sector towards sustainability, are more centered on the environmental dimension, such as the proper disposal of waste, control of the use of restricted substances, use of ecodesign in product development and the use of renewable energy sources, which is corroborated by the examples analyzed in this article. Furthermore, Fletcher and Grose (2012) state that these strategies do not prevent the production of waste and do not cause deeper changes in consumption habits, an important DfS approach. In order to design a new configuration of the production and consumption model in the footwear sector, sustainability must be thought of from systemic thinking, using Design for Sustainability (DfS) approaches that prioritize socio-environmental issues (Gwilt, 2020; Macêdo et al., 2022 and Rinaldi et al., 2022).

According to Kohan et al. (2020), share resources is an efficient strategy for the development of sustainable footwear, thus, the life cycle concept that refers to exchanges (inputs and outputs) between the environment and the set of processes that accompany the phases of a product, might have more potential when designed for a locally based system. In this way, CE and DE can play a strategic role if thought of in a hybrid way, as both models are relevant to design new models of consumption and production in the sector. The growing demand from consumers for more sustainable fashion products and the increased discussion in the innovation agendas of several organizations (Grand View Research, 2020; Footwear Distributors & Retailers of America, 2022), are also potential factors in this discussion.

4 Conclusion

This study contributes with reflections for mitigating the impacts caused by the footwear sector and makes it possible to think the combination of strategies that can carry out systemic changes in the production and consumption model. As pointed out in the theoretical model with the levels of the design intervention, strategies located at the sociotechnical level, where design interventions that focus on promoting radical changes in the way society's needs are met, are potentially more sustainable. Among the examples mapped for this study, it is noted that the use of DfS approaches in the footwear sector is being used in isolation and with greater emphasis on the selection of materials and reuse and recycling processes. Those strategies are located at the lowest levels of the design intervention, and has low impact. Thus, it is possible to conclude that the concept of CE has been much discussed and applied in the footwear sector, however, it can be enhanced if combined with the concept and strategies of DE. The strategies from both models, if thought of in a hybrid way and oriented to the practice of shoe design, combined with Systemic Design, can enable the promotion of greater local resilience for small businesses in the sector, and greater effectiveness in the implementation and realization of sustainable practices. Together, these models can guarantee the maintenance of production and consumption through the strength and union of communities, optimizing the flows and exchanges of resources due to their skills in local production and distribution.

The literature review allows inferring some strategies to implement such models, such as involving local suppliers; explore options for contracting local transport and distribution; form logistical consortiums with other companies in the community. Promoting locally-based sustainability and resilience in the footwear sector through a circular and distributed logic can bring socio-technical benefits to local actors, such as expanding access to infrastructure, enabling proper extraction, production, use and disposal. In addition, the data collected and categorized in the survey of examples, provide a wide repertoire of solutions and good practices for other footwear designers, and can contribute to mitigating the impacts caused by the sector if used as a reference for future projects.

From the perceptions obtained in this article, it is suggested for future studies to understand how the Systemic Design approach can promote resource flows between

production units in the footwear sector in a practical way, as well as how Design for Sustainable Transitions can provide instruments in the transformation of the sector through technological, social, organizational and institutional innovations.

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