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Sustentabilidade e Design Circular: o ciclo de vida dos calçados na indústria da moda

Sustainability and Circular Design: the life cycle of footwear in the fashion industry

Sostenibilidad y Diseño Circular: el ciclo de vida del calzado en la industria de la moda

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Resumo: A indústria da moda, especialmente o setor calçadista, enfrenta desafios significativos relacionados aos seus impactos socioambientais. Este artigo analisa a transição do modelo linear para o modelo circular na cadeia produtiva do calçado, enfatizando o papel estratégico do design como ferramenta transformadora. Fundamentado nos princípios da economia circular, a abordagem crítica sobre o design de produtos, destaca a importância de considerar o ciclo de vida completo, desde a escolha de materiais até o descarte. O estudo revela os entraves e potencialidades da circularidade no design calçadista e discute a viabilidade de práticas sustentáveis por meio da articulação de atores sociais, inovação tecnológica e modelos de negócio disruptivos. Conclui-se que o design circular, quando aplicado de maneira sistêmica e colaborativa, oferece caminhos promissores para mitigar os impactos ambientais e reestruturar a indústria rumo à sustentabilidade

Palavras-chave: design circular; sustentabilidade; calçados; ciclo de vida.

Abstract: The fashion industry, particularly the footwear sector, faces significant challenges due to its social and environmental impacts. This article analyzes the transition from a linear to a circular model in the footwear production chain, emphasizing the strategic role of design as a transformative tool. Grounded in the principles of the circular economy, this critical approach to product design highlights the importance of considering the complete life cycle, from material selection to end-of-life disposal. The study examines both the obstacles and potential of circularity in footwear design and discusses the feasibility of sustainable practices through the involvement of social actors, technological innovation, and disruptive business models. It concludes that circular design, when implemented systemically and collaboratively, offers promising avenues to mitigate environmental impacts and restructure the industry toward sustainability

Keywords: circular design; sustainability; footwear; life cycle.

Resumen: La industria de la moda, especialmente el sector del calzado, enfrenta desafíos significativos relacionados con sus impactos socioambientales. Este artículo analiza la transición del modelo lineal al modelo circular en la cadena productiva del calzado, enfatizando el papel estratégico del diseño como herramienta transformadora. Fundamentado en los principios de la economía circular, el enfoque crítico sobre el diseño de productos destaca la importancia de considerar el ciclo de vida completo, desde la elección de materiales hasta la disposición final. El estudio revela los obstáculos y las potencialidades de la circularidad en el diseño de calzado y discute la viabilidad de prácticas sostenibles mediante la articulación de actores sociales, innovación tecnológica y modelos de negocio disruptivos. Se concluye que el diseño circular, cuando se aplica de manera sistémica y colaborativa, ofrece caminos prometedores para mitigar los impactos ambientales y reestructurar la industria hacia la sostenibilidad.

Palabras clave: diseño circular; sostenibilidad; calzado; ciclo de vida.

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1 INTRODUCTION

Fashion stands as one of the most influential economic sectors on the global stage, generating approximately 1.3 trillion dollars worldwide. It is a highly competitive industry, marked by accelerated growth and significant transformations in its structures and operational dynamics (Gazzola *et al.*, 2020). However, the magnitude of its economic relevance is directly related to the extent of its socio-environmental impacts. Currently, it is considered the second most polluting industrial activity on the planet, largely responsible for the intensive extraction of natural resources, as well as high levels of energy and water consumption (Mota; Silva; Júnior, 2017; Neumann; Martinez; Martinez, 2020). It is estimated that the fashion industry uses more than 98 million tons of non-renewable raw materials, such as petroleum (Gazzola *et al.*, 2020). Its production chain is structured in integrated and interdependent stages, ranging from the acquisition of raw materials, through the manufacturing process, to distribution and final consumption (Andrade; Bezerra; Landim, 2015).

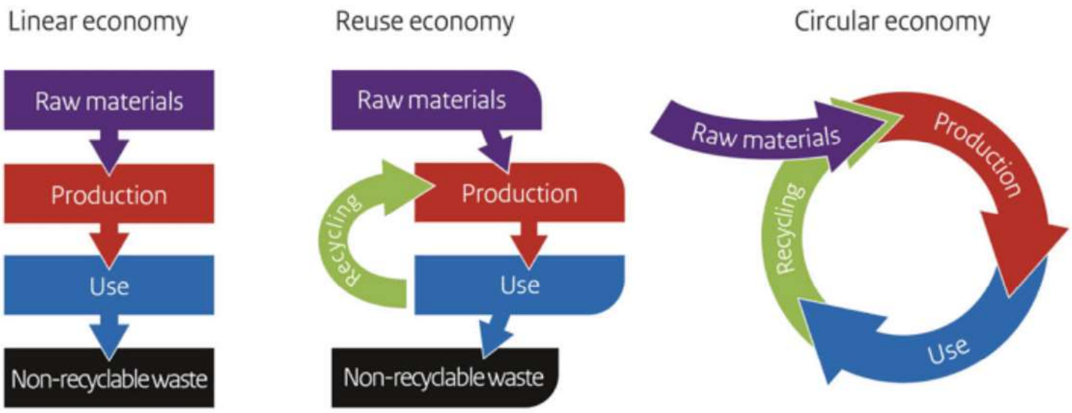
In this sector, consumers play a central role, directly influencing the rapid changes that occur to meet their demands and desires (Gazzola *et al.*, 2020; Rasmussen, 2020). The culture of accelerated consumption, characteristic of contemporary society, has driven the strengthening of the fast fashion model, based on the constant offering of new products at low cost. This model prioritizes the mass production of low-durability items, operating under the just-in-time system, which aims to launch trends within extremely short timeframes (Gwilt, 2015). Although efficient from a production standpoint, this linear model (Figure 1) presents serious environmental and social limitations (Gazzola *et al.*, 2020).

In contrast, there is growing awareness among consumers regarding the damage caused by the fashion industry to the environment and society. This shift in perception has directly influenced purchasing behaviors (Neumann; Martinez; Martinez, 2020). In addition, pressures from public and private institutions have been driving the adoption of more responsible practices in the sector. In this context, sustainability has become a priority topic in academic and institutional debates (Gazzola *et al.*, 2020).

Nevertheless, the idea of "sustainable fashion" carries a conceptual tension, as its terms refer to antagonistic values. For sustainability to be truly effective, a profound transformation in the structure of the fashion production chain is essential (Vadicherla; Saravanan, 2015). The transition from a linear model to a circular model (Figure 1) requires the redefinition of business models, the reconfiguration of resource management, and the alignment between economic development, social responsibility, and environmental preservation. Although some companies are already exploring circular strategies, this change is still gradual and demands integrated technical, financial, and logistical solutions (Gazzola *et al.*, 2020).

In this context, the footwear industry, as a significant part of the fashion sector, faces the challenge of implementing circular design in its products, seeking to ensure the recovery and reuse of materials at the end of their life cycle (Gazzola *et al.*, 2020). Design, in this context, plays a fundamental role in the transition of systems. By rethinking how products are conceived, manufactured, used, and disposed of, design can enable alternatives that articulate innovative solutions integrating functionality, aesthetics, and sustainability, promoting circularity as a structuring principle.

Figura 1 – Transition from the linear economy to the circular economy



Source: (Parate, 2021).

Thus, this article aims to present a perspective on the transition from a linear to a circular system in the footwear sector, highlighting the role of design as an agent of transformation in the construction of new, more sustainable models.

2 CIRCULAR ECONOMY

The circular economy, grounded in the principles of sustainability and industrial ecology, proposes a restructuring of the way products and services are conceived, taking into account their entire life cycle. Its innovative proposal is not limited to minimizing environmental damage, but also aims at the recovery and enhancement of natural capital. In this system, waste is no longer regarded as garbage but instead assumes the role of new resources, contributing to the closing of material loops (Senai-sp, 2020).

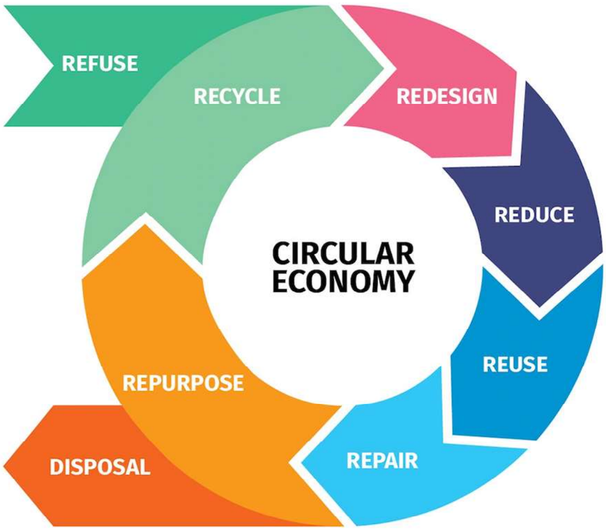
According to the Ellen MacArthur Foundation, three pillars underpin this approach: (i) eliminating waste and pollution from the outset; (ii) keeping products and materials in use for as long as possible, preserving their highest value; and (iii) regenerating natural systems. (Foundation,).

The circular economy therefore proposes the redesign of production processes with a focus on reducing, reusing, and recycling resources throughout the stages of manufacturing, distribution, and consumption. The goal is not only to mitigate negative impacts but to systemically improve product design across production chains (Murray; Skene; Haynes, 2017). To achieve this, resources must be used intelligently within a system that promotes structured circularity, enabling the efficient recovery of materials and waste (Kirchherr; Reike; Hekkert, 2017; Korhonen; Honkasalo; Seppälä, 2018). The circular system relies on the regeneration of materials that are designed from the outset to be reused or reintegrated into new production chains, with minimal loss of value or functionality (Gazzola *et al.*, 2020).

This logic directly impacts all sectors of the economy, especially the fashion industry, which is among those most affected by this paradigmatic transformation (Gazzola *et al.*, 2020). The circular economy is based on restoring economic systems through strategies that primarily include design as a tool to reduce resource waste and foster regenerative practices (Gazzola *et al.*, 2020; Wastling; Charnley; Moreno, 2018). The proposal is to replace the linear model with a cyclical one that promotes both economic and environmental sustainability, within and beyond organizational boundaries. From this perspective, efficient resource management becomes a shared responsibility among all links in the production chain (Gazzola *et al.*, 2020).

The concept of loop closing, central to the circular economy, is grounded in the cradle-to-cradle logic (Figure 2), which contrasts with the traditional cradle-to-grave approach. There are two main types of closed loops: the biological cycle, in which materials safely return to nature; and the technical cycle, which includes strategies such as maintenance, reuse, remanufacturing, recycling, and redistribution (Mccann, 2015; Senai-sp, 2020). Innovation, therefore, must be present from the selection of raw materials to the conception of the product or service, encompassing all phases of design (Senai-sp, 2020).

Figura 2 – Structure of the Circular Economy



Source: (Lakemac,)

With the growing rise of environmental and social concerns, the concept of the circular economy has gained increasing support from companies, governments, and organizations (Slaper; Hall, 2011) . Projections indicate that adopting this approach can drive economic growth, create new business opportunities, generate resource savings, and significantly reduce environmental impacts (Kalmykova; Sadagopan; Rosado, 2018). However, effectively measuring circular actions remains a challenge, making it difficult to assess progress toward sustainable development (Slaper; Hall, 2011).

Among the instruments used to measure the circular performance of products, the Material Circularity Indicator (MCI) stands out. It evaluates aspects such as: (i) the proportion of virgin materials used; (ii) the quantity of recycled or reused materials; (iii) the product's efficiency in being recycled; (iv) the fraction of materials sent to landfill or incineration; and (v) the utility of products throughout their lifespan (Modefica;

Fgvces; Regenerate, 2021). Another important tool is Life Cycle Assessment (LCA), which allows for the analysis and comparison of environmental impacts generated at each stage of a product's life cycle (Pereira; Lima; Rutkowski, 2007).

Data from 2018 already indicated that the implementation of circular strategies could reduce global carbon emissions by up to 56% by the year 2030. This commitment is aligned with the guidelines of the United Nations' 2030 Agenda, a globally agreed framework supported by several international institutions, such as the European Union, the Organisation for Economic Co-operation and Development (OECD), the International Organization for Standardization (ISO), and, in Brazil, the Associação Brasileira de Normas Técnicas (ABNT), which has been developing regulatory frameworks and tools aimed at consolidating the circular economy in the country (Senai-sp, 2020).

3 CIRCULAR PRODUCT DESIGN

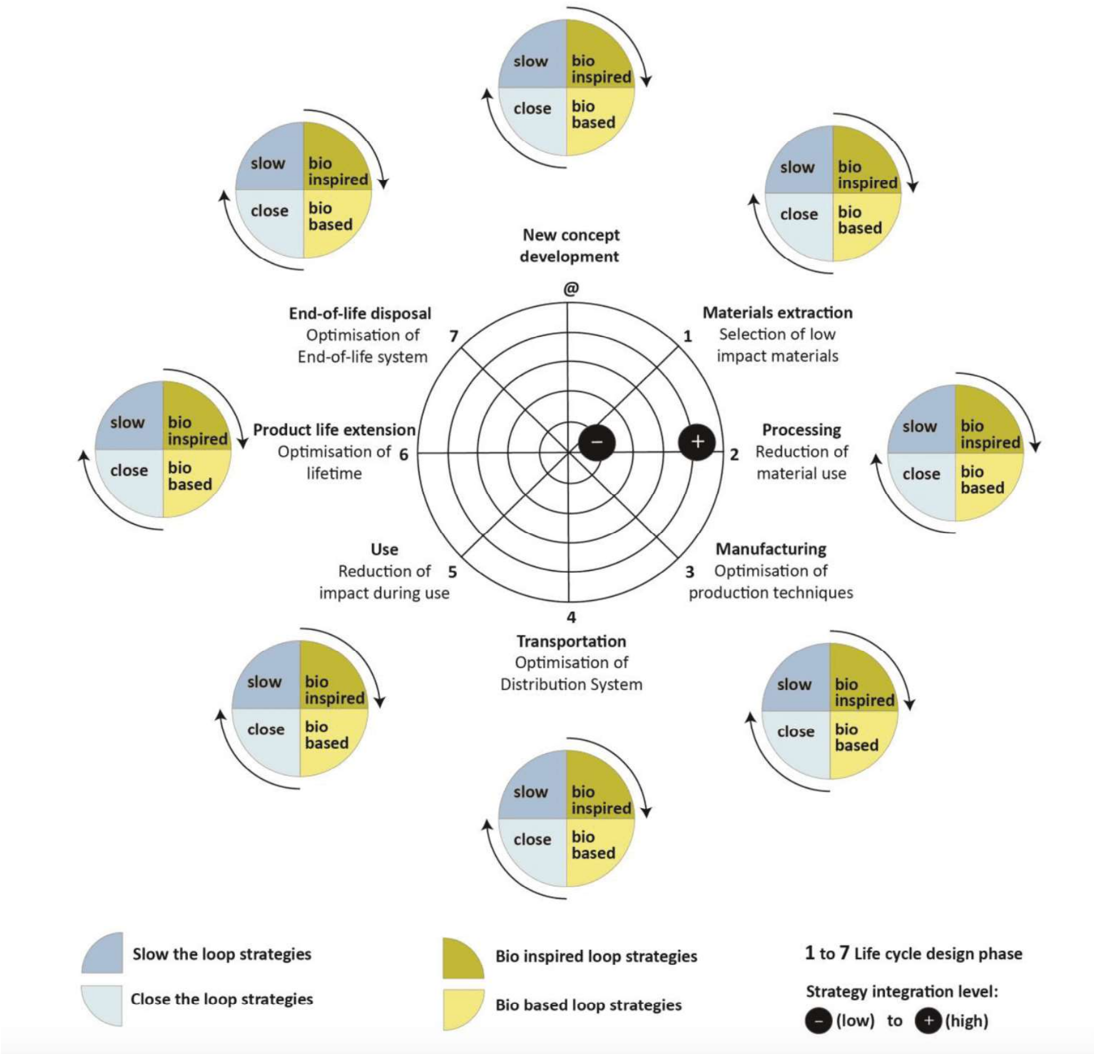
Design is recognized as a key element for enabling the circular economy. Numerous studies in this field present a range of strategies aimed at meeting the principles that guide circular design. Most current research with this focus presents technical approaches that align directly with the tenets of circularity. However, it is essential to emphasize that product development must also consider aspects related to consumer behavior, taking into account their expectations, actions, and needs (Wastling; Charnley; Moreno, 2018) . Beyond functional, ergonomic, and technical requirements, the choice of materials emerges as a critical issue in design protagonism (Herva; Álvarez; Roca, 2011).

Analyzing the environmental impacts of a product from the early design stages allows for anticipating consequences and facilitates more conscious decisions throughout development. In this regard, several authors highlight the importance of intervening at decisive moments in the process to ensure choices aligned with sustainable priorities, especially during the manufacturing stage (Cheah *et al.*, 2013). The work of new design professionals has been guided by more conscious practices, adopting innovative methods and incorporating data that consider ecosystem limits, socio-environmental implications, and material flows (Alessio *et al.*, 2014). These professionals play a leadership role in transforming industrial systems toward minimizing environmental impacts (Júnior; Cândido, 2009).

The effectiveness of circular design depends on systemic restructuring and a shift in design mindset, which includes strategies related to the end-of-life of products, such as take-back and collection systems (Medkova; Fifield, 2016). Planned maintenance should hold the same relevance within the process, alongside the application of the "3Rs" guidelines—reduce, reuse, and recycle—which aim to rationalize resource use and prevent improper disposal in landfills (Júnior; Cândido, 2009; Medkova; Fifield, 2016; Muthu, 2013). Another approach considers that, if the material reaches final disposal, it should pose no environmental risks during its decomposition process (Muthu, 2013). With the structuring of continuous and cyclical processes, materials and components can efficiently return to their respective cycles, extending product durability and multiplying their usage cycles (Medkova; Fifield, 2016).

As observed, the literature presents a diversity of methods and strategies for developing circular products, making it impossible to define a universal formula (Medkova; Fifield, 2016). Instead, it involves a set of tools aimed at creating design solutions that are more resilient and future-ready (Wastling; Charnley; Moreno, 2018). Mestre and Cooper (**??**) proposed a series of approaches that contribute to closing the loop in circular design, including: design for cycle deceleration, design for loop closure, bio-inspired design, and design based on biological cycles (Figure 3). The authors identify circular design as a strategic guideline with great potential for consolidation in the coming decades.

Figura 3 – Multiple Measures for Closing the Loop at Each Stage of the Product Life Cycle



Source: (Mestre; Cooper, 2017)

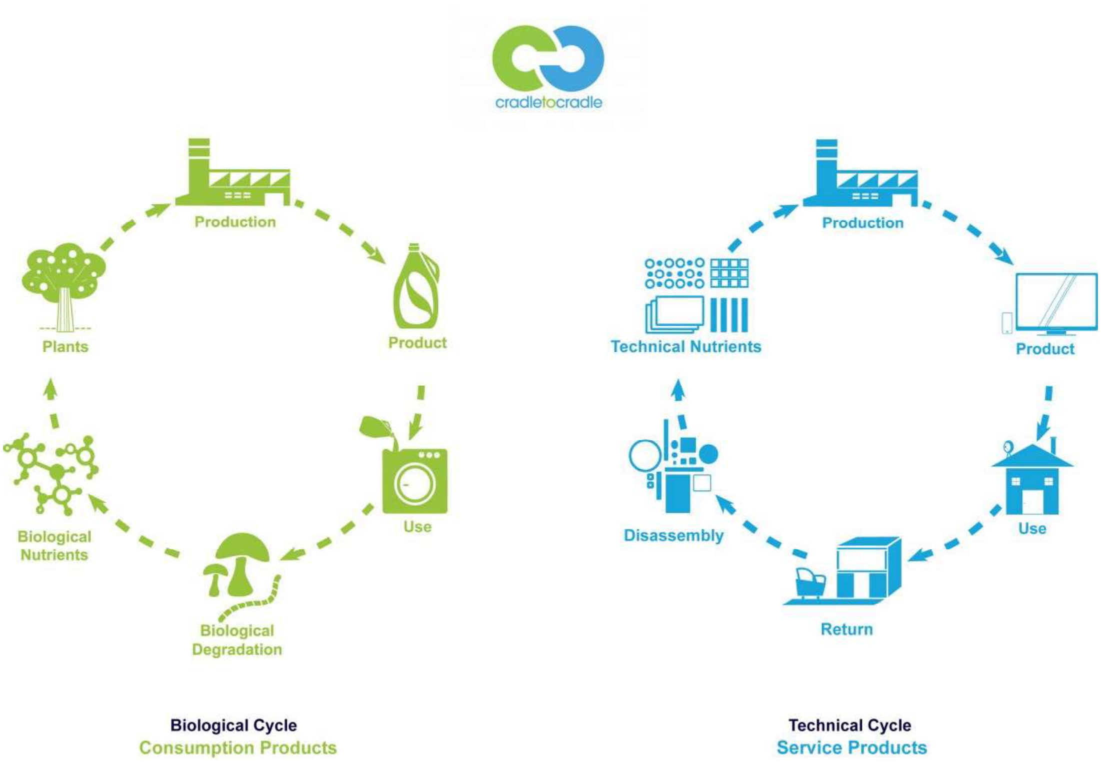
Additionally, other tools have been applied in the design of products with a focus on circularity, with materials playing a central role in this process. The following section explores a more specific approach related to mate

4 TECHNICAL AND BIOLOGICAL LOOP CLOSURE

To address loop closure in the context of circular design, it is essential to understand the cradle-to-cradle concept, in which materials are conceived as nutrients that feed new cycles, analogous to the functioning of nature and its ecosystems. In this way, consumer products are designed to return to the production system as raw materials (Braungart *et al.*, 2017).

Material circularity can be conceived to generate two main types of nutrients: biological and technical (Figure 4). Products may contain elements from both cycles; however, when these components are combined inseparably, they can compromise the efficiency of each process. In certain situations, hybrid composition is unavoidable, requiring careful and conscious design that anticipates proper end-of-life management (Braungart *et al.*, 2017). Coordination among the various agents in the value chain, through information sharing, enables more efficient use of knowledge, contributing to increased productivity and the value of these materials(Kara *et al.*, 2022).

Figura 4 – Structure of the Circular Economy



Source: (Tw,)

The biological cycle is closed when materials are designed to safely return to nature, integrating into the organic metabolism through processes such as composting and biodegradation, thereby nourishing the ecosystem again with the help of microorganisms. In contrast, the closure of the technical cycle refers to materials designed to remain in circulation within the industrial metabolism, maintaining their value and functionality through reuse, re-manufacturing, or recycling, without losing their properties or causing contamination (Abdalla;

Sampaio, 2018; Braungart *et al.*, 2017).

The design of products oriented toward circularity requires not only creativity but also disruptive and innovative business models, with strict criteria for selecting the chemical components that make up the products, ensuring that their end-of-life is compatible with the proposed cycles. In this regard, it is the entrepreneur's responsibility to invest in strategies that enable circular innovation to be implemented effectively and sustainably (Braungart *et al.*, 2017).

5 IMPACTS OF THE FOOTWEAR INDUSTRY AND SUSTAINABLE DEVELOPMENT

The footwear industry has made significant advances in its manufacturing processes, incorporating innovations in machinery and production methods. However, the wide variety of materials used in footwear continues to generate waste that is often toxic, flammable, pathogenic, and corrosive (Robinson, 2009).

The adoption of sustainable practices in the footwear sector is particularly important given the negative environmental impact of its production processes, which frequently involve harmful substances such as chromium, primarily used in leather tanning; petroleum derivatives present in synthetic laminates and various soles; and lead found in specific soles. The hybrid composition of footwear, made up of materials of different types bonded by adhesives and stitching, complicates separation and prevents efficient recycling processes, resulting in end-of-life disposal that is harmful to the environment (Mcdonough; Braungart, 2002).

The disposal stage, at the end of the product's life cycle, faces considerable challenges, especially due to the complexity of materials and the intensive use of adhesives and stitching, generating heterogeneous solid waste that, when sent to landfills, compromises soil quality and water bodies. This situation is exacerbated by the accelerated pace of the fashion industry, which is responsible for increasingly shorter life cycles and growing volumes of production, consumption, and disposal (Ashton, 2017; Francisco; Gonçalves-dias, 2015). The magnitude of this problem highlights the urgent need for a strategic repositioning by companies in the sector, particularly given the large quantity of low-durability footwear that produces a significant volume of waste (Francisco, 2016).

Designing footwear that combines functionality, aesthetic appeal, and large-scale production capability while respecting sustainability principles is a complex challenge (Guarienti, 2018). Studies indicate that approximately 90% of the environmental impacts associated with a shoe's life cycle occur during the raw material acquisition and production stages (Muthu, 2013). Table 1 compares the environmental impacts of three types of materials commonly used in footwear production (leather, synthetic polymers, and textile materials), considering categories such as climate change, human health, ecosystem quality, natural resource use, and water consumption (Chrobot *et al.*, 2018).

According to this study, the extraction and production of raw materials are the main contributors to environmental impacts, with extraction alone accounting for 70% of the impacts in the ecosystem quality category (Figure 5). The analysis covered all stages of the product life cycle and considered global production in millions of tons, using an average weight of 1 kg per pair of shoes as a reference. However, it is worth

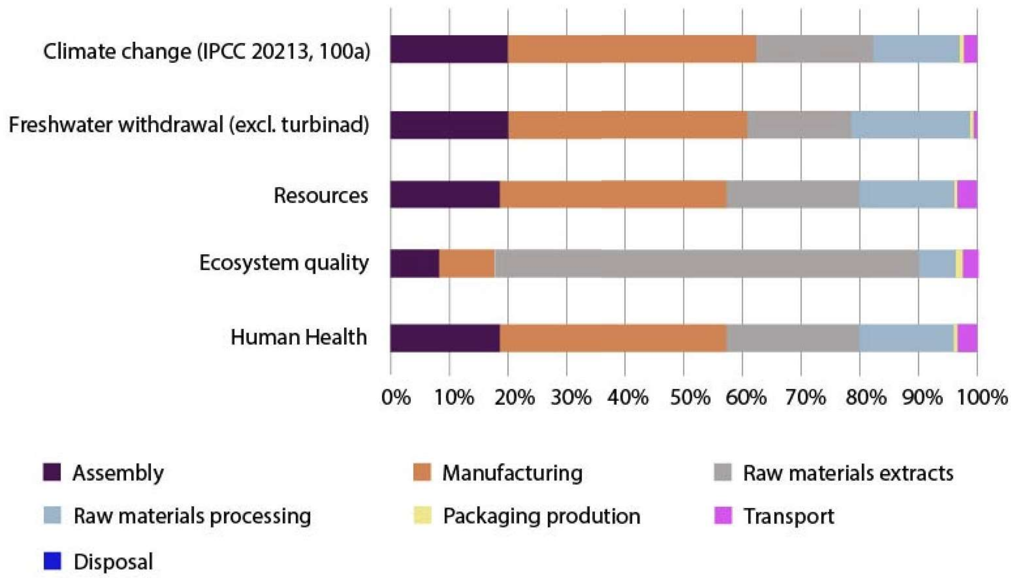
Tabela 1 – Impacts of footwear by material type and category in percentage

Impact Category	Leather Shoes	Synthetic Shoes	Textile Shoes
Climate change	34	50	16
Human health	36	48	16
Ecosystem quality	82	12	6
Resourses	30	54	17
Freshwater withdrawal	31	48	21

Fonte: (Chrobot *et al.*, 2018)

noting that waste generated during manufacturing was not accounted for in the manufacturing category, and the methodology used in the study, while relevant, was not described in detail (Chrobot *et al.*, 2018).

Figura 5 – Impacts of the Footwear Industry by Category



Source: (Chrobot *et al.*, 2018)

Given the significant impacts caused by the footwear industry, amplified by the complexity of its production chain, it is essential to compare the environmental performance of the materials used. The main components include leather, textiles, synthetics, and rubber. Textiles, for example, represent about 7% of urban solid waste, although it is still difficult to precisely estimate the portion corresponding to footwear (Rensburg; Nkomo; Mkhize, 2020).

The growing demand for sustainability is reflected in tools such as the Higg Index, developed specifically for the apparel sector in 2021 by the Sustainable Apparel Coalition, which allows companies to assess the environmental impacts of their products, facilities, and processes (Coalition,).

The significant generation of waste at the end of the product life cycle highlights the need to develop innovative solutions for managing this waste, overcoming challenges related to the efficient and sustainable separation of materials (Pacheco-blanco; Collado-ruiz; Capuz-rizo, 2015; Rensburg; Nkomo; Mkhize, 2020).

Designing footwear to be recyclable requires the use of raw materials that can be reused and easily disassembled, which limits the design and material composition options available to manufacturers (Pacheco-blanco; Collado-ruiz; Capuz-rizo, 2015). Nonetheless, progress is being observed in the sector, with initiatives aimed at replacing hazardous substances and using more environmentally efficient materials (Rensburg; Nkomo; Mkhize, 2020). One of the most promising advances lies in the development of biodegradable materials, motivated by the urgent need to replace conventional petroleum-based inputs (Zhang *et al.*, 2016). Design solutions are increasingly focused on producing footwear using biodegradable, reusable, and recyclable materials; however, no strategic solutions guided by a full life-cycle closure system have yet been identified.

6 FOOTWEAR LIFE CYCLE CLOSURE

Promoting effective sustainable impacts requires systematic approaches. In this context, Life Cycle Assessment (LCA) emerges as a fundamental tool to identify critical points and opportunities for improvement at all stages of products and processes (Tatàno *et al.*, 2012).

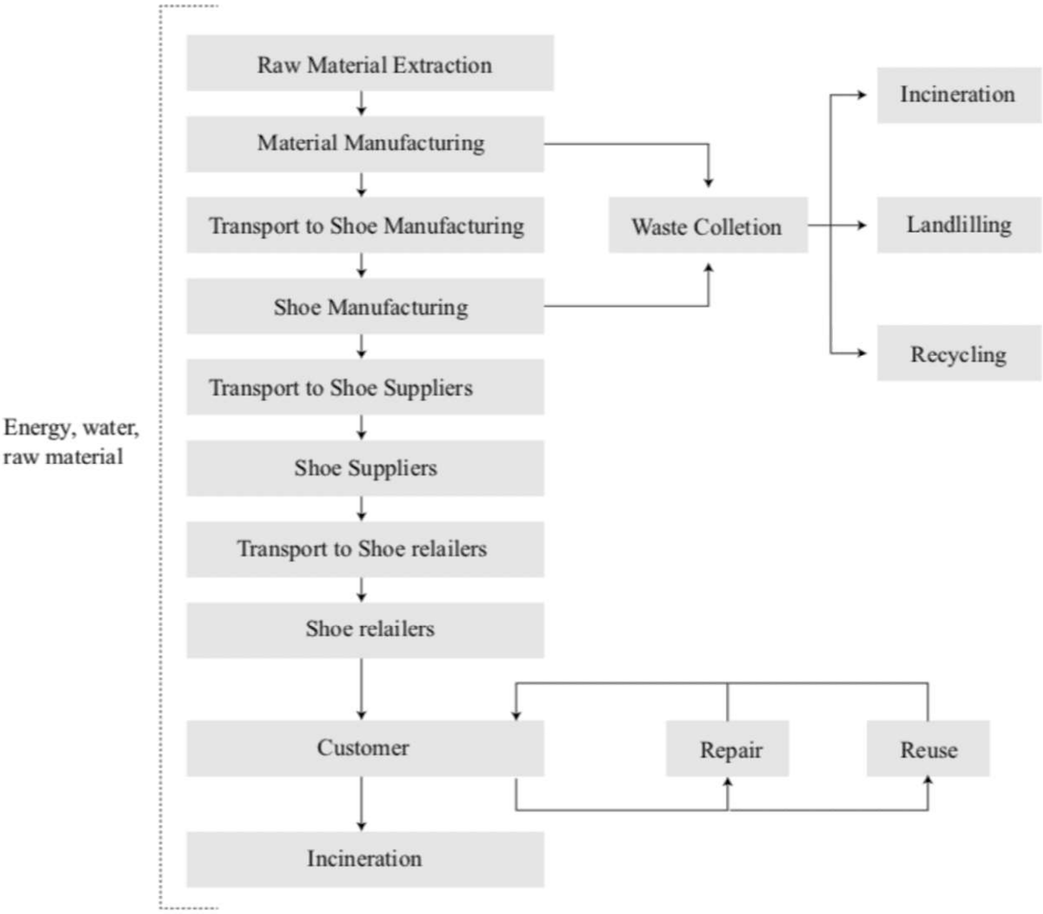
LCA allows for a systematic and scientific analysis of the environmental impacts associated with a product throughout its entire life cycle. The process involves collecting data on the inputs used, assessing environmental burdens, and evaluating potential effects on human health, with the aim of supporting more conscious and sustainable decision-making (Muthu, 2013; Sonnemann *et al.*, 2017).

In the case of footwear, life cycle assessment encompasses the stages of raw material acquisition, production, packaging and distribution, use and maintenance, as well as post-consumer end-of-life management (Gazzola *et al.*, 2020; Tatàno *et al.*, 2012). The initial stage includes the extraction and processing of raw materials. The manufacturing phase refers to the transformation of these materials into finished products, including packaging and logistics. The use phase covers the period of consumer use, while the end-of-life stage involves proper disposal through recycling, reuse, composting, or controlled incineration (Figure 6).

An illustrative example of the footwear life cycle comes from Sweden, where incineration is the predominant solution for end-of-life disposal, according to local waste management guidelines (Gottfridsson; Zhang, 2015). This process reduces waste volume by over 90% and approximately 75% of its original weight. When properly controlled, incineration prevents major environmental impacts and, in some countries, is used for energy generation (Shukla; Cheryan, 2001). Thus, the post-consumer phase highlights alternatives to traditional landfill disposal, such as repair and reuse of components, material recycling, or composting (Manzini; Vezzoli, 2002).

For footwear to be recyclable and enable loop closure via the technical cycle, its structure must be made of materials that are easily recoverable. However, when manufactured with multiple materials, disassembly becomes essential for correct separation and proper allocation of each material, which increases costs and challenges the economic feasibility of the process. Ideally, models should be developed that can be easily disassembled without compromising their integrity during use. One alternative is to design footwear using single-material construction (Figure 7a), which avoids the need for material separation.

Figura 6 – Footwear Life Cycle Stages in Sweden



Source: (Zhang *et al.*, 2016)

Nevertheless, not all recyclable materials guarantee an effective reduction in environmental impact. For this reason, the development of footwear using biodegradable materials has gained attention. These materials allow the shoes to naturally decompose without the need for complex separation or an industrial recycling infrastructure. For biological loop closure (Figure 7b), these wastes should be suitable for disposal with organic waste, undergoing composting processes without causing harm to soil or water resources (Naime, 2011).

7 CIRCULAR DESIGN: CHALLENGES AND POTENTIAL IN INTERDISCIPLINARITY

The circular economy constitutes an interdisciplinary field of research, requiring that its practices and tools be analyzed from a broad and systemic perspective. The adoption of multiple strategies for closing production cycles demands the integration of various social and economic actors in collaborative and coordinated actions. The main challenge of circular design lies precisely in building collaborative networks in which all participants share strategic alignment around a common purpose (Moesch, 2019).

Figura 7 – (a) Footwear made of recycled and recyclable material (b) Footwear made of biodegradable materials

(a) (b)

Source: (Apiccaps, 2021)

The successful implementation of the circular economy depends on the synergy of several factors: business models, product design, reverse logistics, systemic context, and enabling mechanisms. This integration requires the advancement of technologies, strengthening of cooperation networks, transparency in processes, and knowledge sharing (Kuzma *et al.*, 2020).

It is essential to understand the complementarity between two fundamental concepts: eco-efficiency, which aims to reduce negative environmental impacts, and eco-effectiveness, which seeks to maximize positive impacts. The combination of these principles has led to the integration of tools such as Cradle to Cradle and Life Cycle Assessment (LCA). It is important to note that technical recyclability does not always result in actual recycling, just as biodegradable materials do not always reach proper composting processes. Therefore, complementary public and regulatory policies are indispensable to ensure that technical and biological nutrients are properly reintegrated into their respective cycles (Ceschin; Gaziulusoy, 2019).

Portugal has stood out for its strategic advances toward sustainability in the footwear industry. APICCAPS (Associação Portuguesa dos Industriais de Calçados, Componentes, Peles e seus Sucedâneos) developed a strategic plan with goals for 2030 (Table 2), including actions related to products and processes.

Among the plan's guidelines, the application of "Cradle to Cradle" principles, Life Cycle Assessment, and material criticality analysis stand out. These measures reinforce the interdependence between eco-efficiency and eco-effectiveness, contributing to loop closure in the supply chain with long-term environmental, economic, and social benefits.

Based on this premise, implementing circular design in local production arrangements has high potential for optimizing resources and maintaining continuous cycles. Geographic proximity between companies

Tabela 2 – Impacts of footwear by material type and category in percentage

Measures	Actions
Raw Material and Auxiliary Development	· New leathers · Leather substitute materials · Polymers, formulations, and composites; components from biological materials · Sustainable products for tanning or retanning · Water- or bio-based finishes; Water-based adhesives
New Product Concepts	· Products with lower environmental footprint · Products with high thermal and biomechanical comfort · Products with high functional performance · Products and processes "zero defects and zero waste"
Traceability and Sustainability	· Tools for traceability · Tools for cluster sustainability · Eco-design · Environmental footprint assessment · Databases of sustainable materials and technologies
Eco-Production, Processes and Control	· New sustainable and circular production processes for materials, components, footwear, and accessories · Valorization of effluents and production waste · Methodologies and solutions for assessing and controlling new products and processes
Circular Economy	· Business models and management for circularity · Recycling and industrial symbiosis between companies and industrial clusters · Recycling processes for post-consumer products and footwear

Fonte: (Apiccaps, 2022)

within a cluster facilitates collaborative actions, particularly regarding logistics, technological innovation, and alignment of shared interests (Oliveira; França; Rangel, 2019).

Finally, by applying design strategies at each stage of a product's life cycle, as proposed by Mestre and Cooper (2017), it is possible to anticipate which approaches favor circularity. It becomes evident that material selection must consider the interaction between components. Designing for loop closure requires integrated solutions to achieve true circularity.

8 FINAL CONSIDERATIONS

Promoting circular design in this field does not necessarily require sophisticated technologies but rather the ability to redesign traditional models with a more conscious approach. Manufacturers who recognize their environmental responsibility understand the scope of their choices and their influence on cultural transformation within the sector. In this way, companies aiming for circular design advance toward significant improvements in their processes, whether operating within conventional market frameworks or reinventing methods and strategies based on strategic design.

Although there are advances in isolated initiatives, the consolidation of a truly circular system requires coordinated effort among companies, governments, universities, and consumers. Building collaborative networks and adopting regulatory public policies are key elements to overcome technical, economic, and cultural limitations that hinder the closure of production cycles in the footwear sector.

Moreover, interdisciplinarity among design, engineering, logistics, and environmental management is essential for the viability of integrated and resilient solutions. The integration of eco-efficiency and eco-effectiveness, along with the adoption of tools such as LCA and Cradle to Cradle, allows not only for reducing negative impacts but also for enhancing positive effects on the environment and society.

Therefore, circular design is not merely a trend but an urgent necessity in the face of global environmental challenges. Its strategic adoption in the footwear sector can represent a decisive step toward a more regenerative, resilient, and ethical economy.

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