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DECISIO

Sustainable design requirements footwear

Final Report

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Executive summary

Aim of this report

This report addresses the environmental impact of the footwear industry, aiming to formulate sustainable design requirements for footwear to minimise this impact. The large environmental impact is a consequence of the large amount of shoes being produced globally each year, and repairing or recycling shoes is challenging due to the current lack of sustainable design requirements. Adding design requirements for footwear to the Ecodesign for Sustainable Products Regulations[1] (ESPR) can help to enhance the sustainability (including durability, repairability and recyclability) of the footwear.

To adapt to the adjustments initiated by this regulation and to navigate the developments prompted by it, the Ministry of Infrastructure and Water Management has initiated research to gain insights into potential suitable sustainable design requirements for footwear, as well as the potential for inclusion of a mandated percentage of post-consumer recycled content. The research into sustainable design requirements will support the Dutch Government in establishing its position regarding the potential upcoming European ecodesign requirements for footwear.

Methodology

An overview of ecodesign criteria was compiled through literature review and interviews, tailored for footwear design and broader than ESPR requirements. Key characteristics of safety, sport, and casual footwear were identified. Six main ecodesign criteria were selected: design for durability and repairability, recycled input, recyclability, biodegradable sole, extrinsic durability and bio-based footwear. The first four align with ESPR requirements, while the latter two though not directly linked, but are still considered relevant. A SWOT analysis was conducted to assess these criteria, which was further expanded during a stakeholder workshop. Lastly, design requirements for durability, repairability, recycled input, and recyclability were formulated as input for ESPR.

Conclusions and recommendations

1. **Enhancing durability and repairability of footwear are ecodesign criteria that should be prioritised.**

To ensure that footwear on the European market complies with objective durability criteria, the following repairability requirements should be established:

- **Ease of disassembly** : It must be possible to replace and repair the individual components of shoes without damaging or destroying other components.
- **Spare parts**: Spare parts must be made available to all market participants for a specified period of time (e.g. 3 years) and at reasonable prices (e.g.: not more than 20% of total price).
- **Delivery time:** spare parts must be delivered within an acceptable time frame (e.g. 2 weeks)
    - The deadline imposed by the measure must be reasonable to avoid immobilising the product for a period that would make a purchase of a new product more attractive to the consumer.

[1] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32024R1781&qid=1719580391746

- **Repairability information**: Information on the materials used and the tools and steps required to replace parts must be made available to all market participants for a specified minimum period (e.g. 3 years) (e.g. as part of the digital product passport).
- **Repairability standards:** Objective criteria for repairability should be developed specifically for the footwear sector, based on further research.

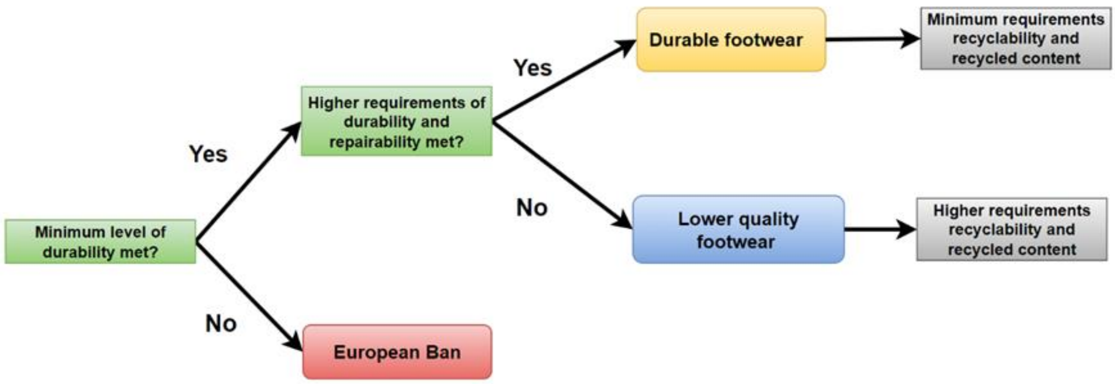
2. **The study identifies two pathways for sustainable footwear.**

Establishing a common minimum durability standard (based on standardized tests like ISO and EN) would be a crucial starting point. Beyond this, the focus should be on encouraging higher durability and improved durability. However, since all shoes eventually reach the end of their life cycle, it is essential that they meet minimum recyclability requirements.

At the same time, many lower-quality shoes such as fast-fashion sneakers are difficult to repair. In these cases, extending their lifespan is challenging, making it crucial to impose stricter requirements on recyclability and the use of recycled materials. Therefore, the two identified pathways are:

- High *durability* and *repairability* and minimum requirement for *recyclability* and *recycled content*.
- Minimum *durability* and higher requirements for *recyclability* and *recycled content*

This principle is summarised in the following flowchart.



Ideally, the perfect shoe from a sustainability point of view should excel in all aspects. High durability and repairability are essential, and even better if it is fully recyclable and made from recycled materials.

If the criteria need to be applicable with a one-step reasoning via ESPR, it would only be possible to set minimum level of durability and minimum requirements for reparability, recyclability and recycled content. In this case, there would be not differentiation between durable and lower quality footwear as illustrated in the flowchart.

3. Conventional design practices limit recycling options. Improved design can enhance the recycling.

Currently, high-quality recycling of footwear is more difficult, as it oftens consists of many small pieces of different materials that are tightly bounded together.

Therefore, minimum recyclability could be imposed on the market. Shoes with lower durability should meet higher recyclability requirements.

- Minimum level of recyclability
  - The product must not contain any electrical or electronic components.
  - No materials harmful to recycling may be used, such as toxic dyes, PVC, or PFAS.
  - Carbon black as colorant for plastics cannot be used, as it limits sorting of the plastics via NIR-detection.
  - The sole and upper must be manually separable.

- Higher level of recyclability, additional requirements
  - Use of at least materials as possible (prioritise mono-material composition)
  - The materials used must be recyclable through mechanical separation.
  - The separation of the sole and upper must be separable with automation (or with very limited labour).
  - No decorative elements that can limit recycling (e.g.: beads)

Further research is needed to determine precise recyclability criteria that are both technically and economically feasible.

4. **Recycled input origins mainly from post-industrial waste, as post-consumer (including closed loop) is less available. A minimum percentage of recycled input could be imposed on the market.**

A minimum percentage of recycled content could be established and imposed on the market by:

- Minimum level of recycled content
  - The sole must contain at least 10% recycled material for example.
- Higher level of recycled content
  - The sole must contain at least 20% recycled material for example.

Under ESPR regulations, it is not possible to set separate minimum percentage requirements for different parts of the shoe. Instead, a minimum percentage can be calculated for the entire shoe by considering the average weight of the sole relative to the total weight of the shoe.

Further research is needed to determine technical and economical feasible recycled content requirement for the upper.

5. **Biodegradable soles are a potential solution to the problem of microplastic generation by footwear sole. Bio-based materials can be interesting for a footwear, but need to be evaluated critically.**

Studies have demonstrated that shoes are a source of microplastic emissions. Microplastics contribute to environmental problems such as ecosystem disruption, water quality degradation and health issues. A potential solution for this problem is the use of biodegradable sole. Ideally these materials should be both biodegradable and recyclable, such as TPU or natural rubber. The phenomenon of microplastics has only been studied relatively recently, therefore further research.

Bio-based footwear is not included under ESPR regulations but has the potential to offer environmental benefits in footwear design. This category is highly diverse, encompassing materials that are animal-based, plant-based, by-products, or not. The environmental gain varies depending on the specific type of material used. Further research is needed to identify which bio-based materials can deliver environmental benefits while meeting technical performance requirements.

6. **Extending extrinsic durability of footwear is crucial, but is difficult to translate into concrete technical requirements.**

The casual footwear industry is driven by fashion trends and aesthetic preferences. Companies release numerous collections each year and consumers often discard shoes for fashion-related reasons rather than due to wear and tear. A more neutral and versatile design could help reduce the overall need for new shoes, making them less likely to be discarded due to changing trends. However, defining this aspect in technical terms is difficult, and therefore it is not considered by the ESPR.

Policy, beyond ESPR, should focus on extending the extrinsic durability of footwear. The government could raise awareness about the overconsumption of footwear and its environmental impact. It would be valuable to conduct research into what defines timeless, neutral, and versatile design associated with a high extrinsic durability for footwear, while also examining the opposite—shoes that are not used anymore due to fashion reasons.

Introduction

Billions of shoes are produced globally each year, creating environmental impacts due to the use of resources and chemicals, production processes and waste generation. Repairing or recycling shoes is challenging, as they are complex products made from multiple materials that are tightly glued or sewn together. For example, a running shoe alone can contain up to 65 different materials and require as many as 360 production steps [2]. Implementing design requirements can help to enhance the durability, repairability and recyclability of the footwear. To improve the environmental friendliness and circularity of products on the EU market, the EU established the Ecodesign for Sustainable Products Regulations[3] (ESPR). The ESPR sets a framework for designing products that e.g. consume less energy, have a longer lifespan, and are easier to reuse or recycle at the end of their life cycle. Within this framework, ecodesign, performance and information requirements, will be developed for various products.

The ESPR serves as the overarching framework, but specific rules will be developed for different product groups. Given the vast number of products on the EU market, regulations are first being designed for the "priority product groups", which are identified based on impact assessments and stakeholder consultations. Footwear is included among these priority product groups. Specific requirements will be introduced, which could focus on a longer lifespan, improved repairability, and the use of less harmful components for these specific product groups. These specific rules will subsequently be formalised through a delegated act, setting performance and information requirements for the product group. Most of the priority product groups are included in the first workplan for 2025-2030. However, for footwear, its inclusion remains uncertain which may result in its implementation being postponed to the second workplan.

To adapt to the adjustments initiated by this regulation and to navigate the developments prompted by it, the Ministry of Infrastructure and Water Management has initiated research to gain insights into potential suitable sustainable design requirements for footwear, as well as the potential for inclusion of a mandated percentage of post-consumer recycled content. This research will support the Dutch Government in establishing its position regarding the potential upcoming European ecodesign requirements for footwear.

[2] Leung, R., & Luximon, A. (2021). Green design. In Handbook of Footwear Design and Manufacture (pp. 459–476). Elsevier. https://doi.org/10.1016/b978-0-12-821606-4.00018-1

[3] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32024R1781&qid=1719580391746

1 Methodology

1.1 Research categories

For this analysis, shoes are classified into three categories as outlined in Table 1 below.

Table 1: categories of footwear in the study

Category Footwear	Explanation
Safety	Footwear designed for workplace protection against hazards such as chemicals, sharp objects, fire, etc.
Sport	Footwear designed for physical activities (e.g. running, football, climbing…) offering protection and support tailored to the specific activity intended for.
Casual	Footwear designed for everyday wear and leisure activities, not intended for safety or sports purposes.

1.2 Research methodology

The study is based on insights from literature review, which are extended with insights from stakeholders' interviews. The key sources used in the literature review are listed in the bibliography, while an overview of the conducted interviews with producers, industry federations, and research institutions is provided in Annex 2.

An online stakeholder workshop was conducted in January 2025, with 9 participants. During this workshop, the SWOT-analysis of the different ecodesign criteria was extended, as the prioritisation of the criteria was discussed. A list of workshop participants is provided in Annex 3.

The research methodology followed these steps:

- Identification of general ecodesign criteria
  - An overview of ecodesign criteria was compiled based on literature review and interview insights. The criteria are tailored towards footwear design and are defined more broadly than solely ESPR requirements. The criteria were classified into three main categories: material, design, and process.
- Characteristics of footwear categories
  - The main characteristics of the three footwear categories (safety, sport, and casual) were identified through literature review and interviews.

- Main ecodesign criteria per footwear category
    - Based on the identified characteristics, main ecodesign criteria were formulated for each footwear category, with potential highest environmental gain.
    - The link between these criteria and the ESPR criteria was established.
    - A SWOT analysis was conducted for different ecodesign criteria using insights from literature, interviews, and a stakeholder workshop.
- Flowchart design requirements
    - A flowchart with specific requirements for the different ecodesign strategies was created.
- Conclusions and recommendations
    - Advice was formulated to guide the position of the Ministry of Infrastructure and Water Management on potential EU ecodesign requirements for footwear.

2 Results

2.1 List of general ecodesign criteria

A general overview of the current-state-of-art in sustainable footwear design is presented in Table 2. These criteria are tailored to footwear design, with some extending beyond the scope of ESPR criteria (e.g.: timeless design).

The ecodesign criteria are divided into three categories: material, design, and processing. Materials and design are inherently interconnected, as a design cannot be realised without materials. Therefore, certain criteria may overlap between the two categories. For instance, the criteria "light" could relate to both material choice and design considerations. Trade-offs can exist between different criteria. For example, a lightweight design may compromise robustness. In such cases, robustness should take priority, ensuring that lightweight materials are optimised without sacrificing quality.

Later in this report, the connection to ESPR criteria will be outlined, and specific ESPR requirements will be proposed.

Table 2: list of ecodesign criteria

Ecodesign criteria	Explanation
Material	
Type	Use materials that contain a minimum amount of recycled content and/or are designed for recycling.
Durable	Chose durable materials with strong tear strength and flex resistance to withstand damage and maintain performance over time. (e.g. leather is very resistant to tearing and flexion)
Non-dangerous	Do not use substances on the "Substances of Very High Concern[4]" and "Restricted Substances[5]" list.
Few	Use minimal materials to facilitate easier recycling at the end-of-life phase.
Design	
Modular	Design for easy repair and recycling. Include features for the detachability and recyclability of parts like soles, heels, and uppers..

[4] The European Environmental Agency identifies Substances of Very High Concern. Once a substance is included on this list, the EU REACH regulation (*Registration, Evaluation, Authorisation, and Restriction of Chemicals*) immediately imposes strict rules and obligations.

[5] https://echa.europa.eu/substances-restricted-under-reach

Robust	Ensure the design is robust and durable and subject to strict quality controls.
Intemporal	Select a timeless (intemporal), multifunctional designs with neutral colours suitable for various occasions.
Light	.Do not use more raw materials than necessary. Avoid unnecessary components. Lightweight design should not compromise durability.
Process	
Resourceful	Optimise use of resources like water and energy, minimise production of solid waste
Clean	Avoid toxic elements (e.g. chromium in leather), and reduce air pollution (e.g. VOCs[6])

2.2 Footwear sectors

In 2023, approximately 98 million pairs of shoes were introduced to the Dutch market[7]. Data from 2021 indicate that the market distribution consisted of approximately 81% casual shoes, 18% sport shoes and 1% safety shoes. In terms of weight, safety shoes are the heaviest (average 1.2 kg per pair), followed by casual shoes (800 g per pair) and sports shoes (650 g per pair)[7].

2.2.1 Casual footwear

The casual footwear industry is primarily driven by fashion trends and aesthetic preferences. To capitalise on this, companies produce numerous collections each year, which contributes to the problem of overstock. In the Netherlands, an estimated 1-5% of shoes introduced to the market annually remain unsold and are ultimately destroyed, although this figure is uncertain[7]. The rise of ultra-fast fashion brands characterised by frequent collections, high volumes, and low-quality products, could further increase these percentages.

In general, shoes are discarded for aesthetic reasons rather than due to wear or functional issues[8]. This creates a significant opportunity to focus on designing timeless, neutral footwear that is versatile across multiple styles. Such designs could reduce the need for frequent collections at the industry level and decrease premature replacements at the consumer level. Unlike safety or sports footwear, casual footwear is subject to less stringent standards. This provides greater flexibility and freedom in terms of materials and design.

[6] Volatile organic compounds

[7] Source: Rebel group

[8] Staikos, Theodoros, et al. "End-of-life management of shoes and the role of biodegradable materials." *Proceedings of 13th CIRP International Conference on Life Cycle Engineering*. Vol. 4. 2006.

In terms of material options, casual footwear offers more possibilities. Some parties in the footwear sector experiment with bio-based materials, and the incorporation of recycled materials. Additionally, leather provides opportunities for durability and easy repairability, extending the product's lifespan.

2.2.2 Sport footwear

Sports footwear occupies a middle ground between casual and safety footwear in terms of technical requirements and aesthetic appeal. While they are not as strictly regulated as safety shoes, they must still meet performance standards to support specific sports activities, such as running, climbing and hiking. High performance is the focus in this sector and while repair initiatives are less common in this sector, they are feasible in certain cases (e.g.: hiking shoes). Unlike casual footwear, sports shoes are less influenced by rapidly changing fashion trends, but they are updated more frequently than safety footwear to align with consumer preferences.

2.2.3 Safety footwear

The safety footwear industry is not driven by fashion or aesthetic considerations. Collections are typically updated only every 5 to 10 years, resulting in significantly less waste from unsold shoes that need to be destroyed, which contrasts sharply with the casual footwear market.

The safety footwear market is highly price driven. Suppliers indicate that customers mainly base their choices on price and are rarely willing to pay extra for sustainability.

Organising separate collection of worn-out safety shoes is relatively straightforward, as these are often returned via the employer. This allows the collection process to be integrated into the company structure, making it easier to recycle the shoes. Moreover, the composition of the safety footwear is similar and therefore there is less variation in the composition of the waste stream, which facilitates the recycling process.

A significant challenge for ecodesign in this sector is compliance with strict regulations. The primary function of safety footwear is to provide protection, and they must meet rigorous ISO standards. This significantly limits the options for material selection and design.

These limitations present a challenge to incorporate recycled materials. Nevertheless, manufacturers have explored possibilities to integrate recycled materials. Most of these materials are post-industrial[9], with the exception of rPET derived from consumer waste used for shoelaces. Alternatives like denim from cutting waste are also being considered for laces. For reinforcing toe caps and anti-perforation steel components, recycled steel is feasible. Recycled polyester, primarily from industrial cutting waste, can be used for the upper part and lining of the shoes. Additionally, recycled foam and recycled rubber are utilised for the soles. An overview of possible recycled materials in safety footwear is given in Table 3.

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[9] Post-industrial waste refers to waste generated during converting or manufacturing process, and sent by industry for disposal, which is not fed back into the production line. It generally consists of a unique feedstock, and are well identified, clean and homogenous (EU Ecolabel, 2016).

Post-consumer residues refer to waste of finished goods that are used by consumer and then collected for waste management. The residues are a mixture and generally contaminated with dirt or other residues, making recycling more challenging (EU Ecolabel, 2016).

Table 3: potential recycled materials in safety footwear

Part	Subpart	Possible recycled materials	Origin
Upper		Polyester	Post-industrial
	Toe cap	Steel	Post-industrial
	Laces	PET	Post-consumer
		Jeans	Post-industrial
Lining		Polyester	Post-industrial
Sole	Insole	Foam	Post-industrial
	Midsole	PU, EVA	Post-industrial
	Outsole	PU, Rubber	Post-industrial
	Anti-perforation plate	Steel	Post-industrial

Some sources argue that workers have the right to request a new pair of safety shoes every six months and, in some cases, this can lead to shoes being replaced prematurely (before their technical lifespan is reached. Addressing this could result in significant environmental benefits. Achieving this requires a mindset shift among both workers and employers

2.3 Main ecodesign criteria for the different sectors

2.3.1 Overview

Based on literature review and interviews, six main ecodesign criteria were identified for the different sectors that can provide potentially great environmental benefits. Figure 1 provides an overview.

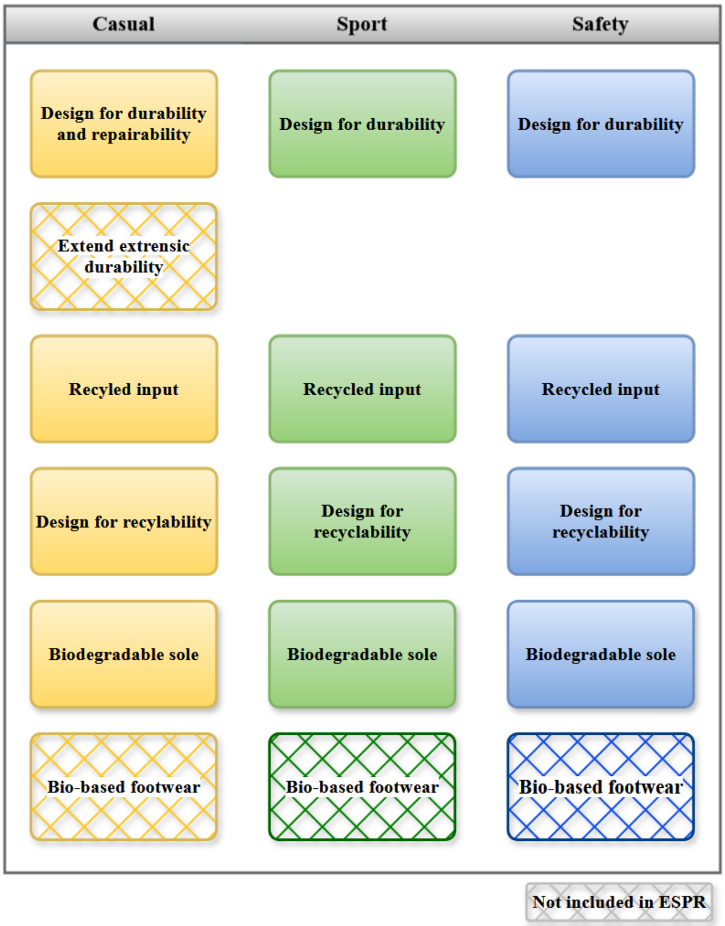

Figure 1: priority ecodesign criteria per footwear category

Table 4 illustrates the relationship between the six ecodesign criteria and the ESPR criteria. All ecodesign criteria aim to reduce environmental impact and are therefore linked to criterion (o) (environmental impacts). Additionally, *"design for durability (and repairability)"* and *"extending extrinsic lifespan"* focus on longer lifetime of the product and contribute to waste prevention (p), as will be discussed later.

"*Design for durability*" enhances product durability (a) and reliability (b), which also facilitates reusability (c). Additionally, "*design for durability and repairability*" ensures that products can be repaired (e), maintained and refurbished (f).

"*Recycled input***"** and **"***design for recyclability***"** have a straightforward link with ESPR criteria use of recycled content (k) and recyclability (m).

Lastly, **"***biodegradable sole***"** addresses the reduction of substances of concern (g), namely microplastics.

The "*extrinsic durability*" criterion does not align with ESPR aspects. This is because the ESPR focuses solely on technical aspects and does not consider aesthetic aspect. In addition, *"bio-based footwear"* is not considered by the ESPR. Nevertheless, we have included these criteria in our study as they can significantly impact sustainability and are therefore relevant eco-design principles to consider.

Table 4: ecodesign criteria and ESPR aspects

Eco design criteria	Extend extrinsic durability	Design for durability	Design for durability and repairability	Recycled input	Design for recyclability	Biodegradable sole	Bio-based footwear
ESPR aspect							
(a) durability		X	X				
(b) reliability		X	X				
(c) reusability		X	X				
(d) upgradability							
(e) repairability			X				
(f) the possibility of maintenance and refurbishment			X				
(g) the presence of substances of concern						X	
(h) energy use and energy efficiency							
(i) water use and water efficiency							
(j) resource use and resource efficiency							
(k) recycled content				X			
(l) the possibility of remanufacturing							
(m) recyclability					X		
(n) the possibility of the recovery of materials							
(o) environmental impacts, including carbon footprint and environmental footprint	X	X	X	X	X	X	X
(p) expected generation of waste	X	X	X				

Link with waste hierarchy

The waste hierarchy[10] (see Figure 2) emphasises that preventing waste is the preferred option. *Waste prevention* includes strategies such as designing for durability and repairability, as well as extending the extrinsic durability. These strategies aim to increase the longevity of footwear and reduce the need for frequent replacements. *Recycle* includes strategies such as designing shoes for recyclability and incorporating recycled materials into the production of new footwear. These approaches aim to transform waste into resources, ensuring materials are kept in use for as long as possible. Finaly, energy recovery and disposal are the least preferred options.

Figure 2: waste hierarchy [10]

A related framework, the "3R Strategy" (Reduce, Reuse, Recycle), launched by the United Nations in 2005, similarly emphasises sustainable resource use.[11]

Aligned with these principles, the Dutch government's National Circular Economy Program (NCPE) identifies four strategies, or "buttons," to improve circularity: reducing raw material use (*narrow the loop*), substituting with sustainable materials (*changing the loop*), extending product lifetimes (*slow the loop*) and recycling materials into high-grade inputs (*close the loop*)[12].

[10] Waste hierarchy is a frame of the European Union that is legally established in the framework directive. It is outlined in Article 4 of the Directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008 on waste and repealing certain Directives (https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A32008L0098).

[11] https ://uncrd.un.org/content/3r-initiative

[12] https://www.rijksoverheid.nl/binaries/rijksoverheid/documenten/beleidsnotas/2023/02/03/nationaal-programma-circulaire-economie-2023-2030/NPCE+Circulaire+Economie+rapport+Engels.pdf

In the footwear industry, a trade-off can sometimes arise between durability and recyclability. For example, leather is a material that is long-lasting and easy to repair. However, recycling leather into high-quality materials can be challenging.

The ideal solution lies in finding synergies between these two approaches—combining durability and recyclability where possible. Innovation can play a key role in achieving this synergies in sustainable design. In addition to durable footwear, some manufacturers focus on creating shoes that may not have an extended lifespan, but are made from low-impact materials that are easier to recycle. Where the trade-off between durability and recyclability cannot be solved, the environmental benefit of durability (extended lifetime) will outweigh the potential recycling loss in most cases. Moreover, current recycling practices in the footwear industry are mostly downcycling. Favouring waste prevention is also in line with the waste hierarchy.

Sometimes, design options can support multiple strategies simultaneously. Modular design, for example, can be an effective tool for improving repairability during a product's lifespan. At the end of its life, it can also facilitate recycling if recyclable materials have been incorporated into the design. This creates a win-win situation, as modular design addresses both repairability and recyclability. However, in some cases, modular design may be applied exclusively for recycling purposes. For example, the Asics Nimbus[13] is a running shoe specifically designed for easy disassembly at the end of its life, even though it is not intended to be repaired.

[13] Nimbus Mirai | ASICS NL

2.3.2 SWOT-analysis

This SWOT analysis delves deeper into various ecodesign aspects, examining their strengths, weaknesses, opportunities, and threats. This approach helps to better understand the broader context surrounding each criterion and add supports the formulation of design requirements and potential minimum standards in the following section.

First, we will discuss aspects that apply to all ecodesign criteria, as summarised in Table 5. Other aspects are specific to individual ecodesign criteria and will be addressed later.

Table 5: SWOT analysis – aspects applicable to all ecodesign criteria

All ecodesign criteria	
Strengths	**Weaknesses**
Lower environmental impact	
Opportunities	**Threats**
Rise of environmental consciousness in companies, sports, consumer.	
Footwear in the ESPR priority list	

An ecodesign criterion is designed to reduce environmental impact. Environmental awareness is steadily growing across industries, including companies, the sports sector, and consumers. With footwear now included in the ESPR priority list, attention to the environmental impact of footwear is increasing. This presents an opportunity for companies to make their footwear more sustainable in anticipation for upcoming regulations.

The following sections will explore the SWOT-analysis of the six main ecodesign criteria.

2.3.2.1 Design for durability (sport and safety)

Sport and safety footwear are both designed with a performance purpose and are typically discarded due to wear and tear rather than aesthetic reasons. A first key opportunity in these sectors would be to extend the technical lifespan of these shoes. Designing footwear with a longer technical lifespan can significantly reduce its environmental impact by lowering the demand for new production, which reduces resource consumption and waste. This is achieved by using durable materials and reinforcing high-wear areas such as the heel and sole. Prolonging the lifespan of products is priority in the waste hierarchy of the circular economy, as it keeps products in use longer and minimises the need for new resources.

Designing more durable footwear not only ensures that customers can use their shoes for a longer period of time, but it also enhances the potential for reuse, as higher-quality shoes remain in better condition. However, ergonomic and hygienic limitations must be considered and researched. Additionally, logistical challenges exist in the collection process, as shoes currently need to be manually paired at textile sorting facilities, which requires significant manual labour. Furthermore, in some cases, one shoe from a pair is lost during the process, making reuse impossible.

When designing durable footwear, companies may possibly experience a reduction in sales volume due to lower product turnover. However, this can be compensated with higher pricing for premium long-lasting products. However, some consumers might resist the upfront cost despite the extended lifespan.

An opportunity could be a new service model where shoes are provided as a service for a specific period of time. Worn-out or damaged shoes are replaced within the warranty period, encouraging manufacturers to produce shoes with the longest possible lifespan. This benefits both the customer and the company. This model is particularly feasible for certain types of footwear, such as safety shoes, as their procurement is often managed within company structures and involves bigger purchases.

Table 6 provides a summary SWOT analysis for extending technical lifetime for sport and safety footwear.

Table 6: SWOT analysis for design for durability (sport and safety footwear)

Design for durability (sport and safety footwear)	
Creating footwear with a focus on longevity, by incorporating durable materials and reinforcing high wear areas (e.g. heel and sole).	
Strengths	**Weaknesses**
Lower environmental impact and resource consumption	Higher economic cost
More potential for reuse	Potential reduction in sales volume, due to lower turnover (weakness in company perspective)
Opportunities	**Threats**
Rise of environmental consciousness in companies, sports	
Footwear in the ESPR priority list	
New business models	

2.3.2.2 Design for durability and repairability (casual)

The design of casual shoes should focus on achieving a long lifespan by using durable materials. Repairability can be improved through a modular design where components such as the heel, sole and upper are easy to separate during repairs. Leather shoes are a good example of modular construction as their design allows cobblers to efficiently replace parts such as soles or heels. Additionally, the ability to disassemble components simplifies recycling, a topic that will be explored later. Low-quality shoes, like certain sneakers where the upper is fused to the sole are harder to repair.

Casual shoes offer more flexibility for modular construction compared to sports and safety footwear because they face fewer functional demands. Sports and safety shoes often need to endure heavy use or extreme conditions, making modularity harder to implement. However, repairability through modularity can still be encouraged in these categories with innovative solutions. Repairability of sports footwear depends on the type of sport shoe. For example, hiking shoes are in practice already repaired, for example by replacing the sole.Emerging technologies, such as 3D printing, provide design opportunities to enhance modular shoe design and production, though they remain in pilot stages.

Another opportunity for durable and repairable shoes is that new business models may also emerge. Some could guarantee footwear quality and include repairs in the purchase. This is more viable for high-quality luxury shoes, such as leather footwear.

Financial incentives can encourage repairability. National repair funds, like those in France, help to partially offset repair costs for consumers. Digital product passports could provide detailed repair information, making it easier for consumers to choose repair over replacement.

Another issue is the decline of the repair industry, which varies by region, reducing access to skilled repair services. Additionally, labour costs make shoe repairs expensive, making customers less willing to repair them even when modular options are available.

Table 7 provides a SWOT analysis of extending technical lifetime through modularity for casual footwear.

Table 7: SWOT analysis for design for durability and repairability (casual footwear)

Design for durability and repairability (casual footwear)	
Designing footwear for longevity by incorporating durable materials and utilising a modular, design for components like the sole and heel to enable easier repairs.	
Strengths	**Weaknesses**
Lower environmental impact and resource consumption	Potential reduction in sales volume, due to lower turnover (weakness in company perspective)
Can simplify recycling	Technical challenges in design and manufacturing
More potential for reuse	

Opportunities	Threats
Rising environmental consciousness	Increasing competition from fast fashion brands
Footwear in the ESPR priority list	Decline of repair industry
3D-printing	High cost for repair may discourage consumers
New business models	
National repair funds	
Digital product passport	

2.3.2.3 Recycled input

A. Casual and sport footwear

Recycled input materials offer a promising option for reducing the environmental impact of footwear, as material production accounts for the vast majority of the shoe's lifecycle impact, according to interviews with industry experts and literature. Utilising recycled materials can help avoid resource depletion and contribute to a more sustainable production process.

However, there are also weaknesses. Recycled materials often come with higher costs than virgin materials, and technical challenges arise when incorporating them into production while maintaining the same quality standards. This can also limit design flexibility. Furthermore, there is a risk of downcycling. For example, PET bottles can be recycled multiple times in its original form, while retaining quality. However, when PET is used in shoes, recycling becomes more difficult. This is because the footwear consist of various small pieces of material that are tightly bound together with other materials. Consumer perception of recycled materials as inferior can also hinder widespread adoption.

On the threat side, there is limited availability of post-consumer recycled materials, which could constrain supply. Additionally, virgin materials often remain more cost-effective, creating competition for manufacturers.

A minimum recycled content requirement could serve as an opportunity to encourage adoption of the criterium. However, a potential risk is that manufacturers might increase material usage for regulatory or marketing reasons. Additionally, recycled content can have lower quality, which could require more material to achieve the same performance. This could increase the overall environmental footprint rather than reduce it, which should be taken carefully in consideration.

Recycled content is more easily integrated into soles, particularly materials like rubber and PU (polyurethane). In contrast, uppers are typically composed of multiple material types, making it more challenging to incorporate recycled content. Nevertheless, recycled polyester and cotton are already used in uppers, highlighting opportunities for further expansion in this area.

Closed-loop recycled input

A closed-loop recycling process, where materials from old shoes are used to make new shoes, is currently challenging in the footwear industry. Unlike clothing, the various materials in shoes are tightly bonded through gluing and stitching. This makes it difficult to obtain pure granulates in the recycling process, as residual glue and traces of other materials remain. As a result, the recycled fractions are used in products like playground surfaced and picnic benches, which is considered downcycling.

At present, the rate of closed-loop recycling in footwear is close to 0%. One industry expert indicated during the interview that a realistic target for 2030 would be around 5% closed-loop recycling. To achieve closed-loop recycling, establishing a dedicated collection system for used footwear is crucial. However, the current volume of separately collected footwear remains limited. Integrating footwear into an EPR system could support the establishment of dedicated collection channels. Currently, nearly half of the footwear processed by recycling facilities comes from unsold stock and sample models. This overstock is primarily associated with casual footwear, as more collections are introduced to the market each year. In contrast, sports footwear typically has fewer collections annually, resulting in a smaller overstock. If regulations were introduced to restrict the destruction of unsold shoes, the volume of available shoes for recycling could decrease significantly. Given the limited volume of footwear recycling, material pooling or indirect recycling loops present another possible option. In this approach, footwear materials are recycled alongside other textile or similar material streams, possibly enhancing efficiency and economic feasibility.

Another challenge with the closed-loop system is the geographical disparity in the recycling process. While waste collection and recycling occur within the EU, the subsequent production of new shoes often takes place outside the EU. Transporting recycled materials over such long distances might be economically less feasible.

Table 8 provides SWOT analysis for putting recycled input in casual and sport footwear.

Table 8: SWOT analysis for the use of recycled input material (casual and sport footwear)

Recycled input (casual and sport footwear)	
Using post-consumer recycled materials as input for the footwear.	
Strengths	**Weaknesses**
Lower environmental impact	Higher cost
Marketing strategy	Technical constraint
	Increased microplastic risk
	Downcycling risk (e.g. PET)
	Consumer perception of recycled content
	Limited design options

Opportunities	Threats
Footwear in the ESPR priority list	Limited availability of post-consumer recycled materials
Regulatory measures	Competition with virgin materials
Material pooling (indirect pooling)	Risk of higher environmental footprint
Integration of shoes in the EPR system of the Netherlands (closed-loop)	Relatively limited separated collection of shoes (closed-loop), even more when regulations destruction of unsold shoes that will limit the waste quantities
	Waste generation within EU, but new shoe production outside EU (closed-loop)

*casual = more applicable to casual footwear

Yellow = specific to closed-loop recycled input

B. Safety footwear

While much of the SWOT analysis applies across different footwear sectors, the aspects highlighted in italic and blue are specific to *safety footwear.*

One of the unique advantages of safety footwear is that it is not focused on fashion or aesthetics. This means the appearance of the product is less critical, allowing for greater flexibility in design options when incorporating recycled materials. Additionally, safety footwear collections typically have a much longer product lifespan. Once a design using recycled content is developed, it can remain on the market for an extended period without the need for frequent updates.

However, a significant weakness in this sector is the requirement to meet strict ISO standards for safety footwear. These regulations impose additional constraints on design and materials, making it more challenging to incorporate recycled content without compromising compliance.

In the context of closed-loop recycling, separate collection of safety footwear is easier to organise, as these shoes are often returned through employers once they are worn out. This allows the collection process to be integrated into the company structure. Despite this advantage in collection, the same challenges for closed-loop recycling as discussed above remain.

Table 9 provides SWOT analysis for putting recycled input in safety footwear.

Table 9: SWOT analysis for the use of recycled input material (safety footwear)

Recycled input (safety footwear)	
Using recycled materials as input for the footwear. The recycled input can be from post-industrial, post-consumer (including closed-loop) origin.	
Strengths	**Weaknesses**
Lower environmental impact	Higher cost (price competition)
Marketing strategy	Technical constraint
Consumers less focused on aesthetics	Increased microplastic release risk
	Downcycling risk (e.g. PET)
	Strict ISO-norms
Opportunities	**Threats**
Footwear in the ESPR priority list	Availability of recycled material
Regulatory measures	Competition with virgin materials
Material pooling	Risk of higher environmental footprint
Integration of shoes in the EPR system of the Netherlands (closed-loop)	Waste in EU, but production outside EU (closed -loop)
Easier separate collection (closed- loop)	
Longer collection lifespan	

Blue = Specific to safety footwear sector

2.3.2.4 Design for recyclability (all footwear)

To ensure that shoes do not end up as waste once they can no longer be repaired or reused, recycling becomes essential. However, recycling shoes is technically challenging because they are composed of various components that are often tightly bonded together. To make shoes recyclable, it is first crucial to select materials that are recyclable. Another crucial factor is minimising the number of different materials used. The more materials incorporated into a design, the harder it becomes to obtain pure material fractions at the end of the recycling process. Finally, detachability plays a key role. Shoes designed with detachable components, using innovative adhesives or other solutions, allow parts such as the sole and heel to be separated before shredding. This separation makes it possible to obtain cleaner material fractions. For instance, a rubber sole could be separated and recycled as a pure fraction. The sole often consists of fewer material types, making it easier to recycle, whereas the upper is typically made of a greater variety of materials, making it more difficult to obtain clean fractions. A detachable design with fewer materials contrasts sharply with how shoes have been constructed over the past decades. As a result, there are significant technical challenges in rethinking design processes, and manufacturing will need to be restructured to align with these new methods. This shift will require initial investments. The challenges are even greater for sports and safety footwear, as the design of these shoes must pass stringent internal performance tests (sports footwear) or comply with strict ISO standards (safety footwear).

Material labelling is an opportunity to facilitate the recycling process. With this technology, materials can be automatically recognised and separated more easily at the recycling plant. A possible threat for the recyclability are patented materials, as there are legals problems with recycling them and offering them again on the market.

Table 10: SWOT analysis for design for recyclability (all footwear)

Design for recyclability (all footwear)	
Recyclable materials, few materials and high detachability	
Strengths	**Weaknesses**
Lower environmental impact	Technical challenges in design and manufacturing
Facilitates (mechanical) recycling and automation	Initial investment
Opportunities	**Threats**
Footwear in the ESPR priority list	Patented materials
Rise of fast fashion	
Labelling of materials	

2.3.2.5 Biodegradable sole (all footwear)

The soles of shoes can be made from synthetic materials, such as plastic. As they wear down during use, they release tiny particles (0.05–5 millimetres) called microplastics. Studies have demonstrated that shoes are a source of microplastic emissions [14] [15]. These particles persist in the environment for long periods and are difficult to remove. Microplastics contribute to environmental problems such as ecosystem disruption, water quality degradation, and harm to animals that ingest them. They also pose risks to human health, for example, through accumulation in the food chain.

Therefore, an important ecodesign criterion is the use of a biodegradable sole, as wear during use causes particles from the sole to be released. An opportunity is the increasing awareness around microplastics. Since the severity and extent of the problem are not yet fully understood, further research on microplastics presents a crucial opportunity for expanding knowledge and developing effective solutions.

Challenges of biodegradable sole include limited design options and potentially higher cost. Additionally, negative consumer perception can exist of sole disintegration during the products' lifetime.

A potential limitation is that biodegradable materials require specific conditions to break down. If sole particles are released in indoor or urban environments, biodegradation may not take place due to the absence of necessary factors such as moisture, microorganisms, and oxygen levels. Another threat is the potential trade-off between biodegradability and recyclability for certain materials. While some, like TPU and natural rubber, possess both biodegradable and recyclable properties, others do not.

Table 11 outlines the SWOT analysis for the use of biodegradable soles.

Table 11: SWOT analysis for biodegradable sole (all footwear)

Biodegradable sole	
Sole made from materials that can naturally decompose, within a relatively short time period into non-toxic elements	
Strengths	**Weaknesses**
Avoiding microplastics	Limited design options
	Potentially higher cost
	Consumer concerns about premature wear
Opportunities	**Threats**

[14] Lee et al. (2021). Microplastics from shoe sole fragments cause oxidative stress in a plant (Vigna radiata) and impair soil environment, https://doi.org/10.1016/j.jhazmat.2022.128306.

[15] Forster et al. (2023). Trail running events contribute microplastic pollution to conservation and wilderness areas. https://doi.org/10.1016/j.jenvman.2023.117304

Footwear in the ESPR priority list	Recycling issues
Increasing awareness around microplastics	Conditions of biodegradation not met

2.3.2.6 Criteria not covered by ESPR

The criteria "*extending extrinsic durability*" and *"bio-based footwear"* are not covered by the ESPR, as previously discussed. However, they remain relevant for further discussion due to their potential environmental benefits.

A. Extending extrinsic durability (casual)

Intrinsic durability refers to the technical lifespan of footwear, which is limited by wear and tear. In contrast, extrinsic durability (also known as emotional durability) is influenced by external factors such as fashion trends.

From a consumer perspective, casual footwear can be discarded for aesthetic reason rather than due wear or functional issues. The casual footwear industry is heavily driven by fashion trends and aesthetic preferences. To capitalise on this, companies produce numerous collections each year, which contributes to the problem of overstock.

A versatile design can reduce the number of shoes consumers need, as such designs are suitable for multiple occasions and can extend the extrinsic durability. Timeless and neutral designs tend to last longer in a consumer's wardrobe, as they are less likely to be discarded due to changing fashion trends. Moreover, for companies, timeless designs can result in fewer collections, which can be sold over a longer period. This helps reduce overstock and waste, creating a significant environmental benefit.

A weakness is that timeless designs may lack trend responsiveness, which could make them less appealing in the current market that is driven by rapidly changing fashion cycles. Product differentiation may be limited.

Neutral designs create opportunities for reuse, as they appeal to a broader audience. Another opportunity lies in adaptable shoes, featuring interchangeable elements such as laces or decorative accessories. This allows consumers to customise their footwear to align with current trends while extending the shoe's overall lifespan.

A key challenge is that timeless design lacks clear, quantifiable criteria. This makes it challenging to implement in policy frameworks. Further research could help to establish more concrete metrics and guide policy development.

Table 12 provides a SWOT analysis of extending the extrinsic durability of casual footwear.

Table 12: SWOT analysis for extending fashion lifespan (casual footwear)

Extending extrinsic durability (casual footwear)	
Using timeless design, versatile design with neutral colours that remain relevant over time.	
Strengths	**Weaknesses**
Significant environmental benefit	Potential reduction in sales volume due to slower turnover
Simple and practical to implement	Limited diversification and trend responsiveness
Opportunities	**Threats**
Footwear in the ESPR priority list	Rising competition from fast fashion brands prioritising trends
Reuse opportunities	Lack of quantifiable metrics
Adaptability (e.g. accessories)	

B. Bio-based footwear (all footwear)

Bio-based footwear is made from materials of biological origin, primarily used in the upper part of the shoe[16]. These materials come in a wide variety, with environmental benefits differing depending on the specific material used.

Some animal-based materials like leather and wool, could be considered as by-product of cattle farming. Because they are considered as by-product, these materials have a low associated environmental impact. Plant-based materials (hemp, cotton, ...) have often a low perceived environmental impact because they absorb CO_2 during their growth. However, their production requires agricultural land, and there is an increasing competition for land for food production, renewables for other sectors (energy, construction) and nature conservation. The use of bio-based materials should not result in the destruction of natural ecosystems, as this would ultimately have a negative environmental impact. Additionally, if bio-based materials are used for one application, another industry or individual may need to resort to petroleum-based solutions due to the limited availability of renewable resources. This means that there will be no net environmental gain. This competition for land is an important consideration.

[16] Bio-based materials are not necessarily biodegradable, just as biodegradable materials are not necessary bio-based. In other words, a material can be both bio-based and biodegradable, but it can also be just one or the other.

Moreover, prioritising bio-based materials for goods could potentially conflict with food security in certain regions, but this falls outside the scope of this study

Further research is needed to identify which bio-based materials provide an environmental benefit and meet technical performance requirements.

Table 13: SWOT analysis for bio-based footwear

Bio-based footwear	
(Parts) of shoe made from materials from biological origin.	
Strengths	**Weaknesses**
Reducing environmental footprint depending on type of material	Higher environmental impact
	Technical constraints
Opportunities	**Threats**
	Competition for land: nature conservation, food, renewables (energy, construction...)

2.3.3 Eco-design criteria and materials

Table 14 provides an overview of materials that align with different ecodesign criteria for footwear. Given the vast variety of types of material used in shoe production, this table is not exhaustive but serves to illustrate the criteria through examples of possible material types.

As discussed, leather is highly suitable for durability and repairability due to its excellent flex resistance and ease of repair for individual shoe components.

For recycled input, commonly used materials in soles include recycled rubber and PU. In the case of safety shoes, recycled steel could also be an option. For uppers, recycled cotton, polyester, and PET are used, though PET has been debated due to concerns about downcycling.

Bio-based footwear includes a wide range of materials, originating from both animal and plant sources. Animal-based options include leather, wool, cashmere, and mohair, while plant-based options include hemp, cotton and bio-EVA. A non-exhaustive overview is provided in the table below.

Table 14: materials associated with the ecodesign criteria

Criteria	Example materials
Durability and repairability	Leather
Recycled input	**Upper:** cotton, polyester, PET **Sole:** rubber, PU, steel (in case of safety shoes)
Biodegradable sole	TPU, TPE, cork
Bio-based footwear	**Upper:** animal-based*:* leather, wool, cashmere, mohair, Plant-based: hemp, cotton, bio-EVA, bio-TPU, coir, sisal, flax, jute, bamboo, pine-apple **Sole**: BIO-EVA, cork, TR Rice shell

2.3.4 Prioritisation of the ecodesign requirements

In addition to expanding the SWOT analysis, the workshop also prioritised the various criteria based on their technical and economic feasibility. The results show that design for durability and repairability, design for recycling, and recycled input are the most feasible in both aspects.

Some consumers wear casual shoes for their fashion characteristics. The lifetime of shoes is sometimes limited by the fashion obsolescence rather than technical lifespan. Only technical lifespan is covered by ESPR. Moreover, research is limited today to be able to determine shoes characteristics that are linked to a shorter lifetime due to fashion obsolescence. Therefore, this criterion is not further developed in this study.

Biodegradable soles and bio-based materials were identified as uncertain areas that require further research to assess their significant environmental relevance. As a result, they were not included in the final selection of criteria.

As a result of the workshop, the final selection or criteria consists of *design for durability and repairability*, *design for recycling*, and *recycled input.*

2.4 Flowchart design requirements

The interviews and the workshop conducted in this study show that footwear experts identify two possible pathways for creating sustainable shoes.

The first focuses on waste prevention by designing shoes that are durable and repairable. Since these shoes will eventually become waste, it is important that they nevertheless meet minimum requirements for recyclability.

Secondly, there are lower-quality shoes that do not last long and are difficult to repair (e.g. fast-fashion sneakers). Since ensuring a longer lifespan is difficult in this case, it is crucial to impose even stricter requirements on recyclability and recycled content.

Therefore, the two identified pathways are:

- High *durability and repairability* and minimum requirement for *recyclability and recycled content*
- Minimum *durability* and higher requirements for *recyclability and recycled content*

The flowchart in Figure 3 illustrates this principle.

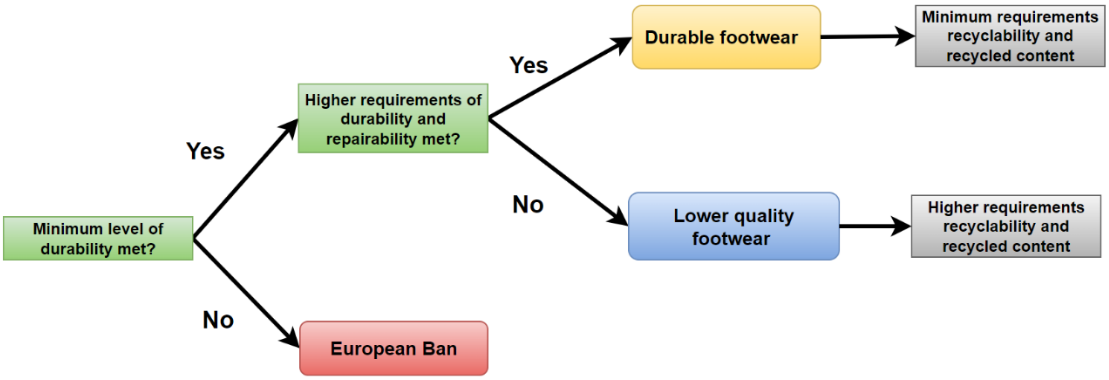

Figure 3: flowchart for sustainable design requirements

However, the optimal footwear has high durability, good repairability, high recyclability, and a high percentage of recycled content. The purpose of the diagram is not to exclude this possibility. However, since this is not achievable for all shoes, it was decided to identify two main groups.

If criteria needs to be applicable with a one-step reasoning via ESPR, it would only be possible to set minimum level of durability and minimum requirements for reparability, recyclability and recycled content. In this case, there would be no differentiation between durable and lower quality footwear as illustrated in the flowchart.

2.4.1 Criteria for durability

A possible requirement for placing shoes on the European market could be compliance with durability criteria. Table 15 provides an overview of concrete tests that determine the robustness of various shoe components through standardised methods. These tests are based on the EU Ecolabel[17]. Values for minimum durability are not currently available in the literature and thus need to be investigated by further research. However, safety shoes are already subject to strict minimum requirements that a shoe must meet before it can be placed on the European market. These specifications are described in the CE mark[18].

The goal of the EU Ecolabel is to distinguish the most environmentally friendly shoes, and the corresponding values in the EU Ecolabel could therefore serve as a threshold to distinguish durable footwear[19]. Further technical research should determine whether the values are still accurate and possibly update these values, given the fact that technologies have evolved since 2016.

[17] https://ec.europa.eu/environment/ecolabel/documents/Footwear-Final_December_2016.pdf

[18] https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:32016R0425

[19] In the EU Ecolabel, seven categories are discussed (e.g., men's town, women's town, school footwear). We have represented the range of these values in the column “high durability”.

Table 15: criteria for durability

Part of footwear	Parameter	Test method	Measurement	Minimum durability	Higher durability (indicative range)
Upper	Flex resistance	ISO 17694	Kc without visible damage	* To be determined (outside scope of study).	*Dry*: 15-100
					Wet: 10-20
	Tear strength	ISO 17696	Average tear force (N)		*Leather*: > 40-80
					Other materials: > 30-40
	Colour fastness of inside of the footwear	EN ISO 17700	Grey scale on the felt after 50 cycles wet		>2-3
Outsole	Flex resistance	EN ISO 17707	Cut growth (mm) + no spontaneous cracks		> 4
	Tear strength	EN 12771	Average strength (N/mm)		*D > 0.9 g/cm^3*: 6-8
					D > 0.9 g/cm^3: 4-6
	Abrasion resistance	EN 12770	Average strength (N/mm)		*D > 0.9 g/cm^3*: <200-400
					D > 0.9 g/cm^3: <150-250
Upper-sole connection	Adhesion or “bondability”	EN 1392	N/mm		>2/5-4
Lining	Abrasion cycles	EN 17704	Number of cycles		*Dry*: > 25600
					Wet: > 3200-12800

2.4.2 Criteria for repairability

In addition to being durable, it is crucial that footwear is also repairable. If for example, the upper and sole are bonded too strongly, repairing the shoe becomes impossible. Therefore, one of the key requirements is that shoes should be designed in a way that allows for replacement and repair of individual components without causing damage to other components. Furthermore, repair information should be more readily available, and spare parts should be provided at reasonable prices and within a reasonable time. Since there are currently few defined technical criteria for what repairability entails, it is essential to establish repairability standards, which would allow for a more standardised approach for regulation.

A summary of the criteria is given:

- **Ease of disassembly** : It must be possible to replace and repair the individual components of shoes without damaging or destroying other components.
- **Spare parts**: Spare parts must be made available to all market participants for a specified period of time (e.g. 3 years) and at reasonable prices (e.g.: not more than 20% of total price).
- **Delivery time:** spare parts must be delivered within an acceptable time (e.g. 2 weeks).
  - The deadline imposed by the measure must be reasonable to avoid immobilising the product for a period that would make a purchase of a new product more attractive to the consumer.
- **Repairability information**: Information on the materials used and the tools and steps required to replace parts must be made available to all market participants for a specified minimum period (e.g. 3 years) (e.g. as part of the digital product passport).
- **Repairability standards:** Objective criteria for repairability should be developed specifically for the footwear sector, based on further research.

2.4.3 Criteria for recyclability

As discussed in the flow chart, it is important that all shoes meet minimum recyclability requirements. Shoes with a lower durability should meet higher recyclability requirements.

Minimum level of recyclability

- The product must not contain any electrical or electronic components.
- No materials harmful to recycling may be used, such as toxic dyes, PVC, or PFAS.
- Carbon black as colorant for plastics cannot be used, as it limits sorting of the plastics via NIR-detection.
- The sole and upper must be manually separable.

Higher level of recyclability, additional requirements:

- Use of as few materials as possible (prioritise mono-material composition).
- All materials must be recyclable, primarily through mechanical separation.

- No decorative elements that limit recycling can be used[20].
  - Examples: rhinestones/spangles, paillettes, glitter, embroidery, stud, pompom, badge, plate, lace, bead, bow, charm.
- The separation of the sole and upper must be separable with automation (or with very limited labour).
  - Examples of technologies that allow for easy separation[21]:
    - Assembling of the upper and sole without glue or stitching (e.g. Loper by Proef design).
    - Use sewing thread which dissolves under heat (e.g. Resortecs) or electromagnetic waves (e.g. wear2).

Appendix 4 provides an overview of best practices to enhance footwear recyclability. However, these serve as recommendations rather than strict regulations, as some components (e.g., fasteners) may disrupt the recycling process but are essential for the shoe's functionality. The guidelines emphasise that durability should remain the overriding driver in design.

2.4.4 Criteria for recycled input

As previously discussed in this report (see 2.2.3 and 2.3.2.3), the majority of recycled input currently used in footwear comes from post-industrial waste. These are easier to utilise as they consist of large, homogeneous streams of relatively pure material. In contrast, post-consumer waste is often collected in mixed batches and need to be separated and cleaned.

Closed-loop recycling (shoe-to-shoe recycling) presents additional challenges, as the upper often contain small, bonded fractions that are difficult to separate. Additionally, the volume of collected shoes remains relatively low at the moment, which limits the percentage of closed-loop input in the sector.

Soles are made of mono-materials, making them more suitable for incorporating recycled content, (whether from post-industrial, post-consumer, or closed-loop sources). Therefore, this study established minimum required percentages of recycled content, specifically for soles.

Minimum level of recycled content

- The sole must contain at least 10% recycled material for example.

Higher level of recycled content

- The sole must contain at least 20% recycled material for example.

Remark: these suggestions are based on a limited number of case studies and not on a market study.

Under ESPR regulations, it is not possible to set separate minimum percentage requirements for different parts of the shoe. Instead, a minimum percentage can be calculated for the entire shoe by considering the average weight of the sole relative to the total weight of the shoe.

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[20] Refashion (2025). Best practice guide on footwear design for recycling. https://refashion.fr/eco-design/sites/default/files/fichiers/REFASHION_BestPractice_Guide_Footwear_V3.pdf

[21] Refashion (n.d). What happens to footwear that cannot be reused? https://refashion.fr/pro/sites/default/files/fichiers/Footwear_mapping_-_4_pages.pdf.

As an illustration, The Footwear Distributors and Retailers of America (FDRA) has established higher targets for recycled input. They have developed an Environmentally Preferred Materials (EPM) guide that outlines an EPM threshold in 2023, which represents minimum recycled content that distinguishes "EPM materials" (sustainable) from traditional ones, according to the industry. FDRA considers this threshold attainable, as it already observed within the industry and encourages companies to go beyond this baseline. In addition, they set out EPM advanced targets, which outline a higher minimum recycled content goal to strive for by 2025, as shown in Table 16. While these targets are not legally binding, they reflect ambitions set by the distributors and retailers organisation to promote sustainability. Although the study focuses on European goals, the global nature of the footwear industry makes these American benchmarks relevant to consider for the European market.

Table 16: minimum % recycled content according to EPM guide by FDRA association[22]

Material	EPM threshold: minimum footwear industry requirements 2023)	EPM advanced targets: Minimum Recycled Content (by 2035)
Synthetic Leather (PU)	20%	80%
Leather	20%	50%
Synthetic fibres (Polyester, Nylon, etc.)	50%	100%
Natural fibres (cotton, hemp, linen, etc.)	50%	80%
Natural Wool	50%	80%
Natural Rubber	20%	50%
Foam	5%	25%
EVA	20%	50%
Thermoplastic (BPU, TPU, PP, TPR, Synthetic Rubber)	20%	50%
Metal	15%	50%

[22] https://www.shoesustainability.com/epm

2.4.5 Criteria for materials (general)

In addition to the newly proposed ecodesign criteria, other EU regulations remain in effect. Materials and substances listed on the Very High Concern List[23] (as determined under the REACH regulation) and Restricted Substances List cannot be used. This restriction applies to all stages, including production, material formulations, homogeneous materials, and final products.

An example of a material listed under REACH is chromium (VI). In contrast, chromium (III), which is widely used in leather tanning, is not subject to this restriction. This tanning method is the most common technique and is applied in approximately 75% of all leather tanning processes[24]. However, chromium (III) also poses health and environmental risks, leading various ecodesign guidelines to discourage its use. Therefore, it is recommended to use alternative methods, such as vegetable-based tanning agents. This study did not assess the economic and technical feasibility of a complete ban on the use of chromium within the industry.

Beyond the raw material itself, the processing methods used can significantly impact the environmental footprint. The EU Ecolabel sets specific standards for production processes, including:

- **Chemical Oxygen Demand (COD)** is a water quality indicator that represents the degree of water pollution and is measured by the ISO 6060 test method. The COD in discharged wastewater shall not exceed 200 mg/l for leather tanning sites, 150 mg/l for rubber treatment and 20 g/kg for textile processing.
- **VOC (volatile organic compounds)** pray significant role in formation of ozone and particulate matter pollution in the atmosphere. The production process shall not exceed 18g VOC/pair and 20g VOC/pair for safety footwear.
- **Water use during leather tanning :** leather tanning can require significant amount of water, making water optimisation key. Limits on water use are set out depending on the type of leather:

Type of leather	Maximum water consumption during tanning process
Hides	28 m^3/t
Skins	45 m^3/t
Vegetable tanned leather	35 m^3/t
Pig skin	80 m^3/t
Sheepskins	180 l/skin

[23] https://echa.europa.eu/candidate-list-table

[24] https://www.neratanning.com/knowledge/tanning-chemicals/

2.5 Instruments

The previous sections outlined the ecodesign criteria for footwear. Several policy instruments can be used to implement these measures. Through the ESPR, it is possible to set minimum requirements for products placed on the EU market. Additionally, there are other possible policy tools, for which , we provide a brief qualitative discussion of the main options below.

- Regulatory obligations (e.g. via ESPR requirements)
  - The EU can set minimum requirements for products placed on the market. These standards must be verified through production declarations, certifications, and audits. Products that do not meet these requirements may face market restrictions or penalties.
  - Examples of obligations include:
    - Minimum durability requirements
    - A minimum percentage of recycled content in production
    - Repairability standards
- Eco-modulation of EPR fees
  - Extended Producer Responsibility (EPR) is a policy tool that shifts the financial and sometimes also the operational responsibility for a product's end-of-life to the producer. This results in contribution towards the waste management of products placed on the market. Through eco-modulations, these contributions can be adjusted based on a product's sustainability. Companies offering more sustainable products pay lower fees, while those selling less sustainable products pay higher fees. This mechanism can incentivise environmental improvements, but its effectiveness depends on the extent of the fee reduction and the cost of redesigning products.
  - For example, in the French EPR system for textiles, bonuses are awarded based on sustainability criteria:
    - 75% bonus for products with high durability and colour fastness.
      - For footwear this could be based on wear resistance of sole and coherence of individual shoe components, according to the Repair Your Pair project [25].
    - 50% bonus for products containing at least 15% post-consumer recycled content
    - 25% bonus for products containing at least 25% recycled content (post-industrial included)
  - However, if eco-modulation is applied to footwear, the percentage criteria should be tailored to align with specific characteristics of the sector.
- Labels
  - Labels help consumers make informed purchasing decisions based on sustainability criteria and encourage manufacturers to improve their products. This can be done via ESPR or other policy instruments.

[25] Repair your pair (2023). Roadmap für einen nachhaltigen Gebrauch von Schuhen. https://www.repairyourpair.com/wp-content/uploads/2023/03/RYP-Roadmap-%E2%80%93-230317-Web.pdf

- Example:
  - Repairability index: a label with different codes could indicate how easy/difficult it is to repair a certain type of shoe. Developing this index requires establishing clear repairability standards and measurement criteria.

Conclusions and recommendations

Conclusion 1. Enhancing durability and repairability of footwear are ecodesign criteria that should be prioritised.

Designing footwear with a longer technical lifespan is achieved by using durable materials and reinforcing high-wear areas such as the heel and sole. Designing for durability can significantly reduce environmental impact by lowering the demand for new footwear, which reduces resource consumption and waste. According to waste hierarchy principle of circular economy, waste prevention should be priority.

Designing durable footwear not only ensures that customers can wear their shoes for a longer period, but it also enhances the potential for reuse, as higher-quality shoes remain in better condition.

Repairability can be improved through a modular design where components such as the heel, sole and upper are easy to separate during repairs.

Recommendation 1. Ensure that footwear on the European market complies with objective durability criteria. Establish repairability requirements.

To ensure longevity of footwear, it can be fruitful to establish objective durability criteria. The EN and ISO standards provide standardised tests that determine the robustness of various shoe components (e.g. minimum flex resistance of the upper and sole). Setting minimum durability requirements as a prerequisite for market approval would ensure that all footwear in the European market meets a basic level of durability. However, further research is needed to determine appropriate threshold values.

To ensure repairability of the footwear, the following criteria could be established:

Performance requirements:

- **Ease of disassembly** : It must be possible to replace and repair the individual components of shoes without damaging or destroying other components
- **Spare parts**: Spare parts must be made available to all market participants for a specified period of time (e.g. 3 years) and at reasonable prices (e.g.: not more than 20% of total price)
- **Delivery time:** spare parts must be delivered within an acceptable time frame (e.g. 2 weeks)
    - The deadline imposed by the measure must be reasonable to avoid immobilising the product for a period that would make a purchase of a new product more attractive to the consumer.
- **Repairability standards:** Objective criteria for repairability should be developed specifically for the footwear sector, based on further research

Information requirements:

- **Repairability information**: Information on the materials used and the tools and steps required to replace parts must be made available to all market participants for a specified minimum period (e.g. 3 years) (e.g. as part of the digital product passport).

However, current research is limited, and further research should determine standards for durability and repairability that are representative and feasible for the footwear sector.

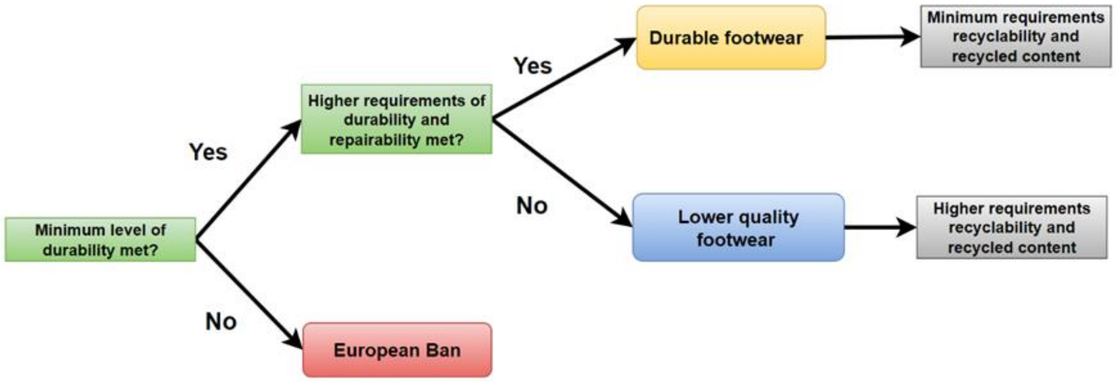
Conclusion 2. This study identifies two different sustainable footwear pathways for footwear put on the market:

- High *durability* and *repairability* and minimum requirement for *recyclability* and *recycled content*
- Minimum *durability* and higher requirements for *recyclability* and *recycled content*

Establishing a common minimum durability standard (based on standardized test) would be a crucial starting point. Beyond this, the focus should be on encouraging higher durability and improved durability. However, since all shoes eventually reach the end of their life cycle, it is essential that they meet minimum recyclability requirements.

At the same time, many lower-quality shoes such as fast-fashion sneakers are difficult to repair, making it challenging to extend their lifespan. For such products, it becomes crucial to impose stricter requirements on recyclability and the use of recycled materials.

This principle is summarised in the following flowchart.



Ideally, the perfect shoe from a sustainability point of view should excel in all aspects. High durability and repairability are essential, and even better if it is fully recyclable and made from recycled materials.

If criteria need to be applicable with a one-step reasoning via ESPR, it would only be possible to set minimum level of durability and minimum requirements for reparability, recyclability and recycled content. In this case, there would be no differentiation between durable and lower quality footwear as illustrated in the flowchart.

Recommendation 2. Ensure that footwear with lower durability on the European market has higher requirements for recyclability and recycled content.

Conclusion 3. Conventional design practices limit recycling options. Improved design can enhance the recycling.

Increasing the recyclability of footwear can help to reduce its environmental impact. Currently, recycling the upper is more difficult, as it consists of many small, interconnected pieces. This makes it difficult to obtain high-quality output fractions. The sole, typically made from a more uniform material, is easier to process. However, in conventional shoe design, the strong adhesion between the upper and the sole makes separation difficult. A detachable design could significantly enhance recyclability by allowing components to be processed separately.

Recommendation 3. Minimum recyclability could be imposed on the market. For lower-quality shoes, these requirements could be higher.

It is important that all shoes meet minimum recyclability requirements. Shoes with a lower durability should meet higher recyclability requirements.

Minimum level of recyclability

- The product must not contain any electrical or electronic components.
- No materials harmful to recycling may be used, such as toxic dyes, PVC, or PFAS.
- Carbon black as colorant for plastics cannot be used, as it limits sorting of the plastics via NIR-detection.
- The sole and upper must be manually separable.

Higher level of recyclability, additional requirements

- Use of at least materials as possible (prioritise mono-material composition)
- The materials used must be recyclable through mechanical separation.
- The separation of the sole and upper must be separable with automation (or with very limited labour).
- No decorative elements that can limit recycling (e.g.: beads)

However, further research is needed to determine precise recyclability criteria that are both technically and economically feasible.

Conclusion 4. Recycled input origins mainly from post-industrial waste, as post-consumer (including closed loop) is less available.

Currently, recycled input mainly originates from post-industrial waste, as post-consumer waste (including closed loop) is less available. Examples of post-industrial waste currently use are cutting waste from polyester, cotton used in uppers, denim used in laces, and rubber used in soles.

Closed-loop recycling (shoe-to-shoe recycling) remains challenging due to the low recyclability of current footwear, making it difficult to obtain pure material fractions. Additionally, closed-loop recycling requires the separate collection of footwear, which is currently limited, resulting in low volumes. At present, half of the input in footwear recycling facilities comes from unworn collections.

Recommendation 4. Minimum recycled input could be imposed on the market. For lower-quality shoes, these requirements could be higher.

Soles are made of mono-materials, making them more suitable for incorporating recycled content, (whether from post-industrial, post-consumer, or closed-loop sources). Therefore, a minimum percentage of recycled content could be established:

Minimum level of recycled content

- The sole must contain at least 10% recycled material for example.

Higher level of recycled content

- The sole must contain at least 20% recycled material for example.

Under ESPR regulations, it is not possible to set separate minimum percentage requirements for different parts of the shoe. Instead, a minimum percentage can be calculated for the entire shoe by considering the average weight of the sole relative to the total weight of the shoe.

Further research is needed to determine technical and economical feasible recycled content requirement for the upper.

Conclusion 5. Biodegradable soles are a potential solution to the problem of microplastic generation by footwear sole. Bio-based materials can be interesting for a footwear, but need to be evaluated critically.

Studies have demonstrated that shoes are a source of microplastic emissions. Microplastics contribute to environmental problems such as ecosystem disruption, water quality degradation and health issues. A potential solution for this problem is the use of biodegradable sole. Ideally these materials should be both biodegradable and recyclable, such as TPU or natural rubber.

Bio-based materials originate from biological sources and come in a wide variety, with the environmental benefits differing depending on the specific material used. Some animal-based materials (leather, wool) can be considered as by-products of meat production. Plant-based materials (hemp, cotton) absorb CO_2 during growth, providing an environmental benefit.

However, the use of bio-based materials should not result in the destruction of natural ecosystems, as this would ultimately have a negative environmental impact. Additionally, due to the limited availability of renewable resources, prioritising bio-based materials in one sector may force other industries or individuals to rely on petroleum-based alternatives, leading to no net environmental gain. This competition for land is a key consideration. Moreover, prioritising bio-based materials for goods could potentially conflict with food security in certain region.

Further research is needed to identify which bio-based materials provide an environmental benefit and meet technical performance requirements.

Recommendation 5. Additional research is needed to determine environmental relevance of biodegradable soles and bio-based materials.

The phenomenon of microplastics has only been studied relatively recently, and further research could help impose restrictions on the use of certain materials in soles.

Bio-based materials may offer environmental benefits, but this depends on the specific material used. Additional research can support more informed decision-making.

Since bio-based materials are not covered under the ESPR, other policy instruments could focus on this matter.

Conclusion 6. Extending extrinsic durability of footwear is crucial, but is difficult to translate into concrete technical requirements.

The casual footwear industry is driven by fashion trends and aesthetic preferences. Companies release numerous collections each year and consumers often discard shoes for fashion-related reasons rather than due to wear and tear.

A more neutral and versatile design could help reduce the overall need for new shoes, making them less likely to be discarded due to changing trends. However, defining this aspect in technical terms is difficult, and therefore it is not considered by the ESPR.

Nonetheless, it remains an ecodesign criterion with significant potential environmental impact. Sensitising consumer on overconsumption can have potential environmental benefits.

Recommendation 6. Policy, beyond ESPR, could focus on extending the extrinsic durability of footwear.

Policy, beyond ESPR, should focus on extending the extrinsic durability of footwear. The government could raise awareness about the overconsumption of footwear and its environmental impact, as consumer behaviour is a key factor in this issue. Raising consumer awareness may encourage people to keep their footwear longer rather than discarding it. It can also help promote awareness of repair options. It would be valuable to conduct research into what defines timeless, neutral, and versatile design associated with a high extrinsic durability for footwear, while also examining the opposite—shoes that are not used anymore due to fashion reasons. It is important that the European Commission takes these behavioural insights into account as much as possible when developing ecodesign requirements.

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Abbreviations

- EN = European Norm
- ESPR = Ecodesign for Sustainable Products Regulations
- EVA = Ethylene-vinyl acetate
- FDRA = Footwear Distributors and Retailers of America
- PET = Polyethylene terephthalate
- PFAS = Per- and polyfluoroalkyl substances
- PVC = Polyvinyl chloride
- (T)PU= (Thermoplastic) Polyurethane
- ISO = International Organization for Standardization
- NIR = near-infrared
- SWOT = Strength, Weaknesses, Opportunities, Threats

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Appendices

Appendix 1. Main shoe components

This classification of shoe components is based on the EU Ecolabel standards[26], and is presented in the table below.

Category Footwear	Explanation
Upper	▪ Covers the toes, top, sides, and back of the foot. ▪ Made from a single piece or multiple assembled parts (e.g., vamp, heel counter, tongue). ▪ Defines the design and style of the footwear.
Lining	▪ Inner material that touches the top, sides and back of the foot. ▪ Materials are selected for flexibility, softness, breathability, and waterproof qualities to enhance comfort.
Sole	▪ Bottom part in contact with the ground ▪ Often composed of multiple layers: outsole, midsole, insole ▪ Designed for flexibility, shock absorption, friction resistance, and waterproofness.

[26] EU Ecolabel criteria for Footwear. https://ec.europa.eu/environment/ecolabel/documents/Footwear-Final_December_2016.pdf

Appendix 2. Overview of interviewees

Organisation Type	Organisation
Footwear manufacturer	EMMA Safety Footwear Footwear
	ASCICS
Retailer	ANWB Retail
Footwear Recycler	FastFeetGrinded
	Circular Footwear Alliance
Federation	European Footwear Confederation
	Textile Recycling Association
Research Institution	Joint Research Center
	Footwear Technological Center of Portugal (CTCP)
Consultant in circular economy	FBBasic
	Rebel Group

Appendix 3. Overview of workshop participants

Organisation Type	Organisation
Footwear manufacturer	EMMA Safety Footwear Footwear
	ASCICS
Footwear Recycler	FastFeetGrinded
	Circular Footwear Alliance
Footwear Repair	Runder Tisch Reparatur
Federation	European Footwear Confederation
	Textile Recycling Association
Consultant in circular economy	FBbasic

Appendix 4. Design for recycling – best practices guide

Recycling disruptors

External disruptors

External disruptors, including "hard points" are elements which can be removed from footwear during a recycling preprocessing stage called "disassembly".

These disruptors are sometimes essential but can be limited in number. Also, grouping them together in the same place on a product can facilitate their removal.

List of external disruptors:

Fasteners	Information transmitters	Functional elements	Aesthetic elements	Removables electrical and electronic components
• Zip/zipper • Button • Hook and eye fastener • Buckle • Clasp • Snap fastener • Snap hook • Brandenburg button/toggle closure • Braiding/ String/cord •Eyelet • etc.	• Brand label • RFID chip • etc.	• Reflective strip • Elastic • Ring • Schank • Heel grip • Hard toe-puff, toe-shell, and puncture-proof plate • etc.	• Rhinestone, Spangles / Paillettes / Glitter •Embroidery • Stud, Rivet • Pompom • Badge, Patch • Flexible or Rigid plate • Lace • Bead • Bow • Charm	• LED light • «Smart" sensor • Heating device • etc.

This non-exhaustive list of external disruptors is given for information purposes only. Some elements may be both aesthetic and functional.

Internal disruptors

Internal disruptors are elements that cannot be separated from the product. They are integrated or inherently linked to the sole, the shoe upper or the footwear product. These disruptors are therefore more problematic than external disruptors. **It is recommended to avoid using them** (or at least to limit them) during the product's design phase

List of internal disruptors:

Finished product	Finishing	Non-removable electrical and electronic components
• Multimaterial (>2)* • All-over decorative element (print, sequins, glitter, paillettes, etc.) • Upper-to-sole stitching • Adhesive • etc.	• Coating • Chemical finish • Carbon black dyeing • etc.	• LED light • "Smart" sensor • Heating device • etc.

**Product final composition with more than 2 different materials.*

This non-exhaustive list of internal disruptors is given for information purposes only.

Recycling facilitators

Recycling facilitators are a range of elements that help in recycling and have a positive impact on at least one footwear recycling stage. The most impactful facilitators are highlighted **in bold**.

List of facilitators:

Shoe upper	Sole	Finished product
• **Single material** • No decorative elements	• **Single material and one piece design** • Sole fastened with hot-melt adhesive of yarn • No decorative elements	•**Traceability and communication of precise material composition** • **Single materials**

If part of the footwear is in textile, please refer to Best practice guide on textiles design for recycling.
NB: This list is valid at the time of publication and will be updated according to developments in the recycling industry.