Understanding the environmental impact of product returns in the fashion industry

The development of a Composite Indicator to provide insights into the environmental and economic performance of product returns for fashion companies

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Delft University of Technology

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by

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Preface

This thesis marked the end of my studies and was written to complete the Master's degree in Transport, Infrastructure, and Logistics at the Delft University of Technology. This research was performed together with Metyis, a data-driven strategy consultancy, who allowed me to combine my interests in sustainability and fashion with my academic skills.

Metyis has allowed me to expand research on improving the fashion industry's environmental impact, which is highly relevant as it is known for its large footprint. My thesis aimed to provide insight into the impact created by product returns on the performance of fashion companies and thereby help them improve their environmental footprint while remaining economically viable.

The interactive collaboration with Metyis has shown me what is needed for companies to effectuate change, as both environmental and economic dimensions are relevant in decision-making. As a result, this research fills scientific research gaps and contributes to practice. The findings of this research will be used by Metyis as a foundation for new sustainable business development and assist companies in improving the impact of their product returns.

This thesis would not have been realized and completed without my graduation committee. First, I would like to thank Daniel Visser for your dedication, support, valuable feedback, and for sharing your expertise. Besides, your talent for connecting the red line and helping to structure my thoughts is something I am very thankful for and have taught me a lot. Secondly, I want to thank Myrthe Rustemeijer for sharing knowledge of the logistics within the fashion supply chain and helping me reach out to experts for interviews. I am also thankful to Mahi Natani for supporting me while writing my thesis. Besides, I am very thankful for everybody at Metyis who helped me to obtain information and made my time at Metyis enjoyable. I am thankful for the opportunities and resources provided by Metyis.

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Last but not least, a big thank you to my family, friends, and E for always being there for support and motivation throughout my studies.

I hope you enjoy reading this research, and it will make you think twice about the environmental impact you create before returning an item.

T.J. Veen
Amsterdam, July 2023

Summary

The fashion industry is a worldwide driver for economic growth [81]. With a growth rate of 9.93% per year (CAGR 2023-2027) [172], further growth is expected in the years to come, particularly within e-commerce [98, 81, 22]. At the same time, the fashion industry's impact ranks the fourth largest on climate change within the European Union (EU), and action is needed to lower its environmental footprint [63, 72, 182]. Most research and efforts focus on sustainability practices in the forward value chain to comply with European Commission (EC) regulations and increased customer pressure [11, 15]. Less attention is paid to returns, although these have become an increased problem in this industry, particularly [36, 183, 15, 66]. High return rates between 25% and 60% in fashion are observed, which are expected to increase further due to the industries' growth [50, 175, 36, 4, 36]. Besides the economic losses for companies due to returns [175], these returns create additional Greenhouse Gas (GHG) emissions, thereby negatively affecting society and the environmental footprint of companies [36, 175, 50, 145, 191].

Returns may account for approximately 12% of the total GHG emissions of fashion companies their operations [9], and they may yearly lose roughly 17% of 1 billion dollars in sales to returns [3, 135]. The growing problem of returns should be tackled by both lowering the environmental impact of the process of unavoidable returns and the number of returns [36, 63], leading to environmental gains for society and cost savings for companies [194]. To accomplish this and effectuate change, companies need transparency and understanding of these returns' environmental and economic impact on their performances [22, 202]. This knowledge is essential for companies to design, analyze, and implement effective strategies to improve their environmental impact while remaining economically viable [23, 36, 182, 202]. However, the impact of product returns is poorly understood, and there is a lack of accurate methods to assess this impact [183, 36].

This research addresses this gap by developing a new performance measurement tool for fashion companies to measure, analyze, and evaluate returns' environmental and economic impact. A new Composite Indicator (CI) was constructed that included all return activities and considered the differences in the return methods. Companies can make well-informed decisions to improve their returns' impact, as environmental and economic performance are considered [182]. In addition, a new benchmark based on GHG reduction targets of the EC for 2030 was designed, developed, and integrated into this CI, allowing companies to compare their performance relative to the targets they must comply with by 2030. With this, a transparent tool was developed where customers and governments know which- and how the environmental impact of a product return is measured for a company's performance. The main question of this research was:

"How can a Composite Indicator be constructed to provide insight into the environmental and economic performance of product returns for companies within the fashion industry and help improve their sustainability?"

The CI was constructed in five steps, where the performance is measured using indicators. First, it was determined which environmental and economic indicators needed to be included in this CI to measure the impact of product returns on a company's performance. This was done using a literature study and expert consultation, and the findings were combined into a theoretical framework. Second, the indicators were normalized by rescaling. Third, the Analytical Hierarchy Process (AHP) technique was applied to weigh each indicator. The indicators were aggregated into one measure in the fourth step using the multiplication technique, followed by evaluation of the robustness of the CI using a Uncertainty Analysis (UA) and a Sensitivity Analysis (SA). Lastly, a benchmark was designed using literature, reports, and expert consultation and developed and integrated into the constructed CI, where AHP weighting was replaced by Equal Weights (EW).

The constructed CI was verified and validated using a case study of a fashion retailer. The results showed that fashion companies could lower their environmental footprint- and costs by using the insights from the CI. Analysis of the performance showed considerable differences in the environmental and economic performance of the return methods. For example, from the analyzed performance of this fashion retailer, it follows that the return method of home pick-up is preferred as it performs best on environmental and economic performance, and in-store returns should be avoided as an alternative for returns. Inspection of each indicator

showed that for home pick-up, transport emissions per return are due to the more efficient transport networks compared to the other return methods. However, home pick-up is more costly as longer distances are driven with relatively expensive distribution vans. In-store returns have lower transport costs as customers bring the product to the brick-and-mortar store, and short-haul transport with expensive distribution vans can be avoided but score worst on transport emissions as no consolidated shipments are used. The obtained insights can be used to define strategies for companies to improve their impact and encourage conscious return behavior of customers. This leads to environmental and economic benefits for a company, as more conscious return choices are likely to be made, and opportunistic return behavior can be limited [194, 22, 23]. Further, the performance was compared to a benchmark that expressed EU target values for 2030. With these insights, knowledge is gained on how far the company is in reaching the goals of the EC to combat climate change. Scenarios were designed using the PESTLE framework, which showed the practical usage of the CI to identify improvement areas and economic risks on their performance. Insights based on the data used in this research show that the most considerable improvements in overall performance can be achieved when fewer products are returned due to more conscious behavior and more packaging material is recycled. Also, charging a return fee to discourage customers from returning items leads to performance improvements and is crucial to lowering costs when governmental financial support is lacking. The insights gathered from evaluating the results of the CI can be used by companies to make more informed decisions, prioritize improvement efforts, and design actions to improve sustainability while ensuring economic feasibility.

The main recommendation of this research is for companies to offer return methods to customers based on their performance and avoid the worst-performing methods as an alternative to returning a product to improve their environmental impact. It is recommended that governments use this transparent tool to compare companies' performances sector-wide. Future research should explore how- and where companies in the purchasing- and return process can use the findings of this study best to encourage customers' conscious return decisions- and behavior most effectively. Next, it is recommended to design return policies using financial discouragements based on the findings of this research. The effectiveness of these policies as mitigation strategies for returns in practice should be explored, where research should be conducted into the effect of implementing financial discouragements on customer demand- and, thereby, the company's profitability. Following, investigating a company's decision-making process on the final destination of a returned product is recommended, as this affects performance. Future research should be done to increase the adoption potential of textile recycling, where both the technical and practical feasibility should be considered for fashion companies. The final recommendation for future research is to investigate governmental policies' role in lowering the number of product returns in fashion and to identify which approach would be most effective, considering legislation and financial support. Here, the designed benchmark and CI of this research are recommended to be included to investigate the effectiveness of implementing these policies and monitor the effects on companies' performances.

Contents

Acronyms

3PL Third Party Logistics Provider

AHP Analytical Hierarchy Process

NCA Non-compensatory multi-criteria analysis

LDPE Low-density polyethylene

CBS Centraal Bureau voor de Statistiek

DEA Data Envelopment Analysis

MRQ Main Research Question

GWP Global Warming Potential

CI Composite Indicator

CR Consistency Ratio

UA Uncertainty Analysis

SA Sensitivity Analysis

GHG Greenhouse Gas

EC European Commission

EF Emisison factor

EW Equal Weights

EU European Union

LCA Life Cycle Assessment

LNG Liquid Natural Gas

LIN Linear aggregation

GME Geometric mean

Definitions

Aggregation
Combining multiple variables or indicators into one measure.

AHP This is a weighting method where weights are assigned based on trade-offs made by experts [133].

Benchmark
A score to which performances are compared, where the benchmark reflects a target or an ideal situation.

Brick-and-mortar store
The physical store of a fashion retailer where customers can buy or return items.

Compensability
If there is compensability, it is allowed that the value of one variable may compensate for the value of another variable. There are certain levels of compensability in which the level of this trade-off between the values is determined [128].

Customer return
A return after the product has been delivered to the customer [45], also referred to as product returns in this research.

CO2e This represents CO2 equivalent emissions, commonly including all GHG emissions [84].

Composite indicator
A Composite Indicator consists of multiple indicators aggregated into one measure in a structured way, where multiple dimensions (i.e., environmental, economic) can be analyzed and compared [206].

Distribution center
A building where packages are redistributed to be transported to retailers, wholesalers, or customers.

E-commerce
Online shopping channel.

EF An emission factor is a value for a specific activity, material, process, or product representing the amount of GHG emissions emitted by this activity, material, process, or product [84].

EW Equal weighting means that the same weight is assigned for all the considered variables [133].

Forward logistics
The logistics network is designated from raw materials to delivering the product to the customer or retailer [45].

Fraudulent returns
Returns that do not conform to legal rules or policies, for example, after wearing an item [91].

GHG emissions
The Greenhouse Gas emissions negatively affect climate change and consists of carbon dioxide (CO_2), nitrous oxide (N_2O), methane (CH_4), sulfur hexafluoride (SF_6), hydrofluorocarbons ($HFCs$), perfluorocarbons ($PFCs$), and nitrogen trifluoride (NF_3) [85].

Indicator
A variable that can measure the performance of a process, system, or action [206].

LCA A life cycle analysis assesses the emissions created over the whole life cycle of a product, including the moment of cradle until it goes into the grave [130].

Legitimate return
Returns made by a customer who intends to keep a product when they purchase it but eventually decides to bring it back [146].

Normalization
Converting data to a comparable range or scale by transforming the unit of measurement [150].

Opportunistic returns
When the decision to return is already made before purchasing the product, for example, when different sizes or colors are bought of an identical product [123].

PESTLE framework
This is short for Political (P), Economic (E), Social (S), Technological (T), Legal (L), and Environmental (E). This framework is used to get an overview of contextual factors [148, 198].

Performance gap
Quantification of the difference between two values, commonly between target and actual performance.

Product return
See consumer return.

Radar chart
A chart with multiple axes, represented by spokes. Each spoke represents a different variable, making it possible to combine and analyze multiple data points in one figure.

Reverse logistics
The reverse flow of goods in a supply chain, where a product is transported from the customer back to the final destination (point of recovery or a different user) [45].

Rescaling
Normalization technique based on minimum and maximum values in a data set [134].

Sensitivity Analysis
Increasing and decreasing input values for the model to examine the effect on the final value of the model.

Third Party Logistics
The external party that provides transport of packages, including the logistic services. Examples of these are PostNL, UPS, and DHL.

Uncertainty Analysis
The process of analyzing the uncertainty sources in the model and examining their effect on the output [133].

Validation
Validation investigates whether the model is right by looking at the requirements and objectives [143].

Verification
Verification investigates whether the constructed model is the right model based on the conceptual model [104].

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1 Introduction

This chapter introduces the research focusing on improving and understanding the environmental impact of product returns in the fashion industry. The structure of this chapter is as follows: first, the background of the research is elaborated on, followed by the scientific and practical problems. Next, the research scope, objectives, questions, and design are described.

1.1. Research background

The fashion industry is a worldwide driver for economic growth and has transformed significantly over the past decades [81, 63]. With a growth rate of 9.93% per year (CAGR 2023-2027), further growth is expected in the years to come, with a market volume of 1.382 billion euros predicted by 2027 [172]. A driver for this growth is the notable shift towards online shopping in the fashion industry [36]. With COVID-19 acting as a catalyst and further digitalization developments, it is estimated that the total sales of e-commerce will primarily increase in fashion [81, 22]. E-commerce offers benefits to customers, such as a more comprehensive selection of products and prices, access to reviews, multiple delivery options, and an easy return of unwanted products [163]. Fashion retailers benefit from this new sale channel as well because it can boost their sales, and they have access to a broader customer audience [175]. However, with the increase in e-commerce sales, the number of returned customer products in the fashion industry is growing as well [50, 145]. [175] mentions return rates of 50% in fashion e-commerce, [36, 4] find that 25% of all fashion products ordered online result in return, and for some product categories, returns rates of 60% are observed [37]. In comparison, less than 10% of products bought in offline retailing environments are returned [36].

In parallel to the industry's considerable market size, the fashion industry's impact ranks the fourth largest on climate change within the European Union (EU) [63]. Nearly 10% of worldwide Greenhouse Gas (GHG) emissions are attributable to the fashion industry, which is twice as much as all maritime and flight transport combined [112, 72]. Every second, a truckload of clothes is either incinerated or sent to landfills [52, 63]. The fashion industry must lower its environmental footprint to meet EU targets and respond to market pressures of customers that demand improved transparency on sustainability practices, while remaining profitable in a competitive environment [63, 182]. This makes, with the expected growth in demand and volume, sustainability a challenge and opportunity for the fashion industry [63]. The European Commission (EC) has implemented regulations and initiatives to lower the industry's environmental impact as part of their broader efforts to reach net zero by 2050 [48, 72]. An important initiative that supports this objective is the Green Deal. This initiative states that the GHG emissions of the fashion industry should be reduced by 50% by 2030 and eventually become climate neutral by 2050 [72, 63]. To support the Green Deal, the EC plans on introducing mandatory sustainability reporting for companies, in which companies need to provide transparency on their performances. The mandatory sustainability reporting will be a basis to monitor and control companies' environmental impact, identify improvement areas, and prioritize reduction efforts [62].

To lower its footprint, the fashion industry continuously adopts and integrates sustainability practices throughout the value chain [63, 182]. Most of these efforts are focused on the forward supply chain [15, 11], where most emissions along the value chain are created [12]. The reverse logistics, notably the effects of product returns, have received little attention [36, 183, 15]. However, product returns have become an increased problem in this industry, particularly [36, 183, 175]. Increased return activities have exacerbated its environmental footprint, which is expected to rise further due to the industries' growth [50, 145]. Besides the economic losses for companies due to returns [175, 191], the EC also recognizes the environmental impact of returned products as a widespread problem within the EU [66]. So, actions should be taken to reduce this impact [63, 36].

Returns must be repackaged, transported, warehoused and stored, recovered, or disposed to landfill or incineration. This increases energy consumption, GHG emissions, and other forms of environmental waste [36, 22, 183]. A logistic firm estimates the GHG emissions of transporting returned items in the USA in 2022 to be bigger than those of 5.1 million cars driven for one year, which equals over 24 million metric tons of GHG emissions [178, 141]. 4.3 billion kilograms of returns end up in landfills in the USA alone, equivalent to 10500 fully loaded Boeing 747s [141]. Looking at the worldwide scale, it is evident that returns create a negative impact on the environment that only grows with the rise of e-commerce [50, 145]. Although returns are not the largest proportion of the industries' GHG emissions along the value chain [12], they create undesirable consequences for society and companies [33, 66].

Yet, the impact of returns is unjustly, often not taken seriously by companies. Effective management of these often lacks, even though returns create high costs and companies are accountable for the environmental impact they create [157, 50]. A report of a UK retailer, ASOS, analyzing their business in 2018-2019 estimates that 12% of their total operational emissions are accountable to returns, which increases as the volume of returns in their business grows [9]. With the current developments and e-commerce growth in the industry [98, 171], it is likely to assume that returns have become a larger share of the total operation emissions at the company level. In addition, returns are, in essence, costly for companies, as expenses are made while the product loses value due to its short fashion life cycle [22, 6, 183, 66]. The returns costs can sometimes go up to three times compared to their original price [183]. A study by the National Retail Federation has found that for returns in the USA, merchandise companies pay 166 million dollars for every 1 billion dollars in sales [3, 135], emphasizing the economic losses and, thus, the relevance for companies to lower their returns from an economic viewpoint as well.

Customer returns should not be overlooked in the fashion industry's transition to meet their GHG emission targets, which is the focus area of this research. Companies should take action to, on the one hand, lowering the number of returns and, on the other, improve the current process for unavoidable returns [36, 66]. Besides reducing negative externalities on society, improving returns can lead to economic gains for companies.

1.2. Research problem definition

This section defines the scientific- and practical research problems.

1.2.1. Scientific research problems

The scientific problem discussed in this research is that there is no understanding of the environmental impact of product returns. It is acknowledged that knowledge and transparency on the environmental impacts of product returns could improve sustainability [202, 23]. However, a method to measure this impact lacks [183, 36]. In the scarce attempts to assess product returns, not all relevant logistic activities involved in product returns are included. Research does not include the GHG emissions, and not all return methods available nowadays are considered, although this is decisive for the environmental impact created [51]. Also, the impact of returns on a company's performance is not known yet. There is no overview to compare the return methods based on their environmental performance in the literature, which would be needed to encourage more conscious return behavior of customers [22]. Therefore, it can be concluded that research into the environmental impact of product returns in this sector still shows shortcomings and further research into this topic is needed.

This research aims to add knowledge to the scientific literature on reverse logistics in the fashion industry, focusing on the environmental understanding and assessment of customer returns. Several contributions will be made in this study to scientific research. The first contribution is adding scientific research to the currently limited field of research on consequences and potential solutions to the environmental impact of product returns in the fashion industry. The second contribution is a new model for measuring the GHG emissions of product returns in the fashion industry that include all relevant logistic activities and return methods. The third contribution is the development of a new Composite Indicator (CI) for product returns that fashion companies can use to measure, analyze, and evaluate the impact on their environmental and economic performance. This study also contributes by expanding the field of research on company performance measurement with CIs by assessing both environmental and economic performance [203]. Also, a new benchmark expressing target performance is developed based on reduction targets of the EC to combat climate change and integrated into the CI to benchmark the measured performance. The final contribution is that a new overview and measurement method is created where insight into the impact of different return methods is gathered. This makes the return methods comparable based on their environmental and economic performance. Although it is acknowledged in the literature that choosing a return method based on its performance might lead to improved environmental impact, this insight is currently lacking in scientific research [51, 22].

1.2.2. Practical research problems

Besides the economic losses of returns, fashion companies are responsible for the environmental impact they create [50], and with the increase in returns, this will be exacerbated. With the prospected mandatory environmental reporting and targets to combat climate change, companies must measure, improve, and give transparency on their performances to comply with EU regulations [62, 59, 72]. [12] notes that although returns are not the biggest cause of emissions along the value chain of a fashion company, there is abatement potential for companies to both lowering returns and improve the processes. Reducing returns by 20% saves 12 million tonnes GHG emissions, which an improved process of returns can further improve[12]. So, the problem of returns should be tackled by both lowering the environmental impact of the process of returns and the number of returns [36, 63], leading to environmental gains for society and cost savings for a company [194].

Environmental improvements can be made by adopting practices to lower the impact of each activity within the return process [36]. To do so, there is a need to understand the environmental and economic impact of product returns in the fashion industry and how this affects a company's performance. Companies lack the tools to measure the impact of product returns on their environmental and economic performance and thereby face issues in identifying areas of improvement. A return method can perform best based on environmental performance but can also be the highest-cost alternative for a company. This knowledge is essential for companies to design effective strategies to improve their environmental impact while remaining economically viable [23, 36, 182]. However, companies do not yet have the tool to analyze, assess, and compare the environmental impact of product returns on their performances [36]. Companies cannot identify areas of improvement, prioritize their reduction efforts, and measure and monitor their performance, making it difficult for them to improve the environmental impact of product returns.

Additionally, fashion customers increasingly demand transparency and information to make more environmentally friendly decisions. Informed customers are more likely to choose environmentally friendly return methods, leading to environmental gains for society as a whole [23, 12]. Also, creating awareness of this impact to customers might lead to fewer products being returned due to more sustainable shopping behavior in which customers are likelier to keep the products they buy [194]. Still, companies lack understanding and cannot inform or provide transparency about the environmental impact of return methods and their behavior [22, 202].

This research is used to fill the following practical knowledge gap:

There is a gap for fashion companies in understanding how product returns and different return methods impact their environmental and economic performance. It is unclear which actions they should take to lower the environmental impact of product returns while considering their economic feasibility. As a result of this shortcoming, companies cannot provide transparency about their environmental impact or inform customers to make more conscious choices for their returns to improve sustainability.

The practical objective is to develop a transparent tool for companies to understand and measure the impact of product returns on their performances. With this study, companies can see how implementing different actions or strategies would improve their environmental performance, gain detailed insights, and compare them with each other, while remaining profitable. Further, companies are provided with knowledge of how far they are in reaching the reduction targets of the EC to combat climate change and how different actions could contribute to this. Last, companies are provided the knowledge to inform their customers and encourage conscious return behavior.

1.3. Research scope

This section discusses the research scope, which consists of the system boundaries of the process product returns and some practical limitations, which environmental and economic impact are measured. Lastly, a conceptual overview is presented to improve understanding of the research.

1.3.1. System boundaries

Returns happen throughout the supply chain and are categorized by [45] as manufacturing, distribution, and customer returns. This research only focuses on customer returns; this type of return happens when the product has been delivered to the final customer [45]. This research intends to focus on the whole process of a return and consider all logistic activities that are crucial in analyzing the environmental and economic impact. The boundary defined for this process of product returns in this research starts from the customer requesting a return until the disposition of the product is executed [45, 15]. This is visualized in Figure 1.1. With this boundary, the forward delivery of the product is excluded from this research.

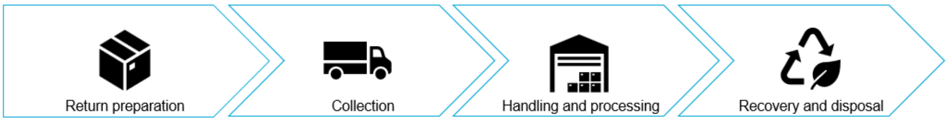

Figure 1.1: Research scope, source: (Author)

The recovery and disposition of products are included in these process boundaries because it substantially contributes to the environmental impact of a product return and thereby affect a company's performance [15, 93]. Product disposal consists of recycling, landfill, incineration, and reselling activities [36]. These activities generate additional costs and emissions for a company that would not have been made if the product would not return [107]. So, including the disposition activities will provide a complete assessment of the environmental and economic impact of a product return on a company's performance.

1.3.2. Practical limitations

The returned products in this research examined are ordered at a fashion retailer, delivered to the customer, and returned to the retailer for one of the acceptable reasons to return. This research excludes used products that are returned for recycling purposes from the research scope, as these are commonly not returned to the same retailer when handed in for recycling, according to an expert in clothing recycling. Also, insights into this stream of used products are lacking for companies, according to an industry expert, and it is often not considered by fashion companies as part of their reverse streams.

The environmental and economic impact is assessed per product item returned. For practical reasons, it is chosen to employ an average-sized clothing item that fits in a medium size e-commerce parcel box. This box size is commonly used for transporting clothing items [34]. Further, the geographical scope considered in this research is customers based in the Netherlands. The distribution and accessibility to collection points, physical stores, and other facilities are within this geographical area if not mentioned otherwise.

Further, this research uses legislation and policies set by the EC, focusing on companies operating under European laws.

1.3.3. What environmental impact is assessed

The EU has marked the reduction of GHG emissions in Europe as the top urgent and most critical priority to ensuring climate neutrality by 2050 [67]. This research aims to contribute to this goal and therefore focuses on measuring the environmental impact of GHG emissions. Measuring the GHG emissions rather than solely carbon emissions provides a complete overview and assessment of the environmental impact. The different activities that create and contribute to GHG emissions are identified and calculated. There are six GHG according to the Kyoto Protocol: carbon dioxide (CO_2), nitrous oxide (N_2O), methane (CH_4), sulfur hexafluoride (SF_6), hydrofluorocarbons ($HFCs$), perfluorocarbons ($PFCs$), and nitrogen trifluoride (NF_3) [85, 84]. All these are harmful to the environment and contribute to climate change, so an accurate assessment is made by concentrating on the GHG emissions. Additionally, by focusing on the GHG emissions of logistic activities in their value chain, the measurements can be easily compared to the objectives and targets of the EC as they are in the same unit of measurement [60]. For example, by measuring transport GHG emissions, the targets can be easily translated, and progress can be tracked, providing relevant results for companies and customers [58]. Finally, a lot of reliable information, data, and tools are available for measuring GHG emissions, which helps improve the assessment's quality. Therefore, the environmental impact of product returns is measured by the GHG emissions.

The GHG emissions are expressed in CO2 equivalent emissions (kgCO2e), also referred to as CO2e. This measure incorporates all main greenhouse gasses (CO_2, N_2O, CH_4, SF_6, $HFCs$, $PFCs$, and NF_3) into a single measurement unit [84]. These emissions are converted to CO2-equivalents according to the Global Warming Potential (GWP) [26, 84].

1.3.4. What economic impact is assessed

This research only includes the company's costs to perform a product return, considering the scope of this process. According to industry experts, return costing by fashion companies is preferably activity-based, so only activities in the process are considered in the economic impact assessment. This is also consistent with how the environmental impact is assessed, which is also on an activity basis. The lost revenues due to returns are not included in this analysis, as this is difficult to estimate for the level of detail of this research, negatively affecting the assessments' quality. The costs are determined in euros per returned item. The base case data originates from 2020, defining the (if needed) conversion rates.

1.3.5. Conceptual understanding of the research

To get a better idea of the process of returns, what is evaluated within this research, and how this is quantified, Figure 1.2 is created. This is a conceptual model explaining the return phases, the activities that can happen within each phase, and how the environmental and economic impact is measured in this research. All elements will be elaborated in more detail in chapter 2.

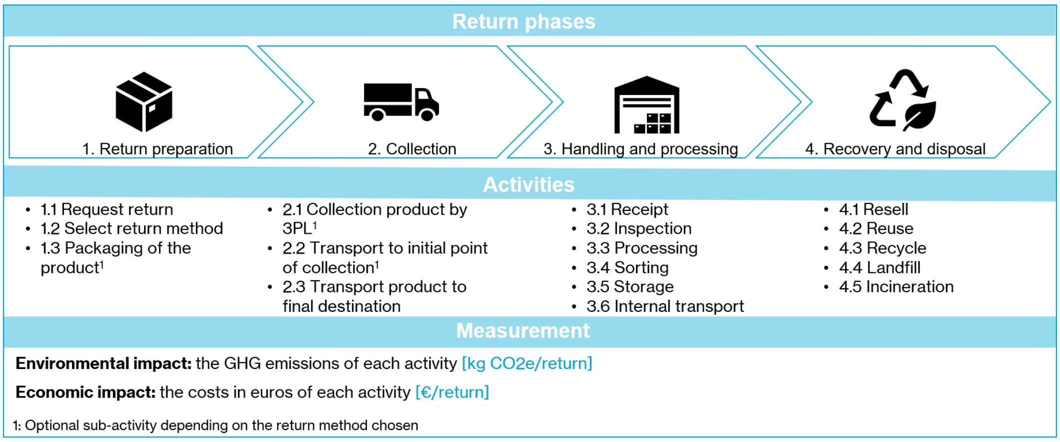

Figure 1.2: Conceptual model of the scope of this project, source: (Author)

1.4. Research objective

The objective of this research follows from the reviewed literature and defined problem statements. This study aims to assess the GHG emission impact and economic costs of product returns in fashion and to create an understanding of this impact on a company's performance. With these insights, a measurement method to analyze the environmental impact of product returns is created, closing this scientific research gap. Also, companies are provided insights on improving the environmental footprint of returns, as both environmental and economic dimensions are included to ensure feasible decision-making. The outcome is a CI that assesses the impact of the process of returns using indicators that quantify the activities within the process, considering the return method chosen.

The following research objective is defined:

To develop a measurement approach fashion companies can use to assess and evaluate the environmental and economic impact of product returns on their performance, that includes all relevant activities within the process of returns and return methods, and apply this to practice by developing a Composite Indicator (CI) for fashion companies to improve sustainability.

1.5. Research questions

The Main Research Question (MRQ) is formulated following the research gaps and objectives:

"How can a Composite Indicator be constructed to provide insight into the environmental and economic performance of product returns for companies within the fashion industry and help improve their sustainability?"

The following sub-questions are set up to answer the MRQ:

1. What does the fashion industry's product return flow look like?
   (a) What return methods can be used to return a fashion product?
   (b) How do the activities of the return process differ depending on the chosen return method?
2. How can the environmental impact of the various logistic activities involved in product returns be assessed?
   (a) What are the key factors that should be considered for assessing the environmental impact of these logistic activities?
   (b) How can the environmental impact of these factors be measured?
3. How can the economic impact of the various logistic activities involved in product returns be assessed?
   (a) What economic factors should be considered for assessing the economic impact of these logistic activities?
   (b) How can the costs of these factors be measured?
4. How can a CI be created to assess the environmental and economic impact of product returns?
   (a) How can companies use a CI to assess their performance on multiple dimensions?
   (b) Which steps need to be performed to construct a CI for a multi-dimensional assessment?
   (c) What methods should be selected to construct the CI for product returns assessing environmental and economic performance?
   (d) How can the current state of a company's performance be measured using the CI?
   (e) How can the constructed CI be verified?
   (f) How can fashion companies use the constructed CI in practice?
   (g) How can the constructed CI be validated?
5. What is a company's most preferred return method considering its environmental and economic performance?

1.6. Research design

The research uses a structured set-up, which is elaborated on first. Based on this set-up, the research outline is presented. A summary of the expected research output is given, followed by an overview of the data sources used in this research.

1.6.1. Research set-up

This research involves a combination of qualitative and quantitative data analyses. The research structure is based on the DMADV process (Define, Measure, Analyze, Design, Verify) [184], which has its roots in the Six Sigma theory. This is a general framework for structuring research development using an organized approach. DMADV is used to design or improve new products, processes, or services [165]. As this research intends to develop a new model instead of improving a product or process, adaptions are made to this framework in consultation with W.W.A. Beelaerts van Blokland (2023).

For this research, the Measure phase (M) is replaced by a Conceptual phase (C). This research designs a new measurement method, so a conceptual model must be developed first. Further, the last step of Verification (V) is replaced by Evaluation (E). Verification is already built-in during the design phase, as the designed model must be verified before being evaluated. In the evaluation phase, the designed model is tested to understand how the model performs, and validation is done. An additional phase is added to this framework, which is the concluding phase. It is essential to reflect on the findings and limitations of the new model, which is incorporated in this final phase.

First, the context, objectives, and scope of the problem are defined. Additionally, a literature review and expert consultation will identify the critical variables for measuring the performance of product returns and develop the methodology for constructing the CI. In the second phase, a conceptual model is developed with the findings from the literature on product returns will be applied to the literature found to construct a CI. The specific methods to construct the CI for this research will be chosen, the conceptual model will be developed, and an overview of the required data will be made. The third step is to analyze the company's performance by building a base case using the created CI. This step involves preparing the data, measuring the base case, and concluding the findings. Next, the benchmark will be developed in the design phase. The benchmark will be tested, evaluated, and verified. After successfully verifying the model in the design phase, insights are created into how companies can use the model in the evaluation phase. This will be done by developing scenarios tested with the constructed CI, which will validate the model. In the concluding phase, the main findings are presented together with the limitations and recommendations of this research.

1.6.2. Research outline

In Figure 1.3, the outline of this research is visualized. The blue boxes represent the methods used for each step. This research has eight chapters, structured in the Define, Conceptual, Analyse, Design, Evaluate, and Concluding phases.

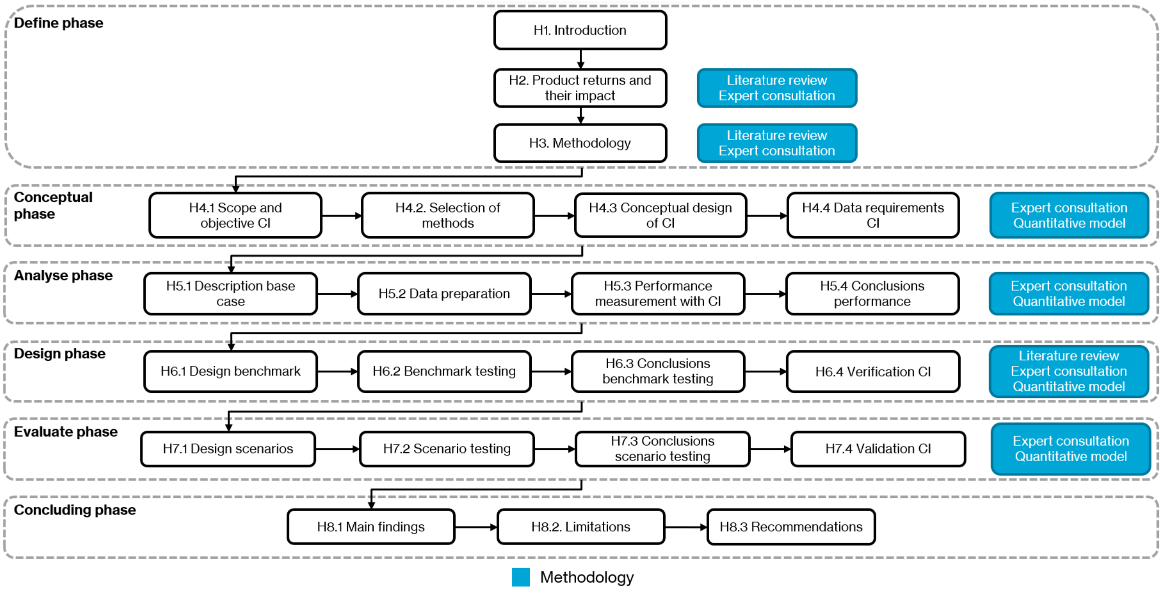

Figure 1.3: Research outline, source: (Author)

1.6.3. Expected research output

An overview of the expected research outcome is as follows:

1. An overview of the return process in the fashion industry, including the activities that take place and how these differ for each return method.
2. Insight into the activities in the return process that create environmental impact and how they can be measured.
3. Insight into the activities in the return process that create costs and how they can be measured.
4. Construction of a CI for measuring and assessing the environmental and economic performance of returns for a fashion company.
5. Insight in how fashion companies can make a trade-off between their environmental and economic performance of product returns using a CI.

6. Design of a benchmark that represents target performance for fashion companies.
7. Prove of usage of the CI by performing a case study using data from a fashion company.
8. Discussion on how the performance of return methods differs and which method is preferred or should be avoided.
9. Discussion on improvement areas and risks for companies by evaluating different scenarios.
10. Discussion on the academic and practical implications of this study.
11. Discussion on the research limitations.
12. Recommendations for further research.

1.6.4. Data sources

This research uses both quantitative and qualitative data. Literature was used to create an understanding of the return process, identification of environmental and economic factors, and how these factors can be measured. Relevant articles were found using the following electronic search engines: SCOPUS, Scholar Google, Web of Science, and TU Delft Repository. Expert consultation and interviews supplemented the reviewed literature and verified data using industry knowledge. These interviews were conducted with internal experts from Metyis, a data-driven strategy consulting firm specializing in the premium fashion industry and digital commerce. Metyis understands and has expert knowledge of global fashion retailers, supply chains, and businesses. Additionally, Metyis has experience, provision, and understanding of many business data on fashion retailers. Also, external experts were interviewed. These external experts were questioned based on their expertise; an expert specializing in recycling post-usage clothes was contacted better to understand the recovery of returned products in this research. An expert within finance and banking was interviewed to gain further insights into the costs and substantiate scenario developments. An expert with industry knowledge of GHG accounting for businesses was interviewed to understand better how this works and what methods companies can use. Additionally, an expert working at a large warehouse of fashion cooperation is interviewed, and further insights are obtained on the actual return process and how costs are acquired in practice. Further, literature was used to select an appropriate methodology for this research, clarify the choices made for the method used, and develop the construction of the model. The model is implemented using Python and Excel. The data for the base case originates from a client of Metyis. The considered data was measured for one whole business year.

2

Product returns and their impact

This chapter will study the determinants for assessing product returns' environmental and economic performance using a literature review supplemented with expert consultation. This chapter is structured as follows: First, it is explained why products are returned in section 2.1. Next, the return process is elaborated on in section 2.2, followed by a concise overview of the return methods. In section 2.4, the environmental impact of the return process is analyzed, identifying factors and measurement methods for assessing the environmental impact. Lastly, the cost factors of the return process and the measurement methods for these factors are mapped in section 2.5. In this chapter, sub-research questions 1,2, and 3 will be answered, respectively: *What does the fashion industry's product return flow look like?*, *How can the environmental impact of the various logistic activities involved in product returns be assessed?*, and *How can the economic impact of the various logistic activities involved in product returns be assessed?*

2.1. Why fashion products are returned

In both online and offline channels, customer returns are offered. Customer returns refer to products returned after delivery (or purchase in offline environments) to the customer [45]. According to European laws, customers who purchase a product online hold the right to return their purchase within fourteen days. Companies are thus legally obliged to offer this service even though the product does not show any flaws. In offline environments, companies are not obliged by law to directly provide an exchange or refund when a product is returned, except if the product shows defects [71]. However, returns can still be offered to boost sales or when companies feel like they have to, as their competitors are offering it [45].

Customers return products for a variety of reasons. Repairs, warranty of returns, end-of-use, end-of-life, wrongly delivered product, damage, and customer fraud are mentioned as general motives [45]. Returns can be categorized as legitimate, opportunistic, and fraudulent. Legitimate returns refer to returns made by a customer who intends to keep a product when they purchase it but eventually decides to bring it back. Opportunistic returns happen when the customer knows they are returning a product before the purchase, such as when they buy identical products in multiple colors and sizes [123]. Fraudulent returns refer to customers who return products even though it is not by legal rules or regulations, for example, after wearing an item [91].

An explanation for the high return rates in particularly fashion is the uncertainty customers face when they purchase an item online. Customers who shop online experience a higher chance of a mismatch between what they expect from a product and what they receive [175, 127]. Due to incorrect sizing information or undetailed and inaccurate product descriptions, customers receive unwanted products which they send in return. Misfit and sizing issues account for 42% of the reasons for a return within e-commerce [126]. Therefore, customers tend to purchase multiple variants of the same product to increase their likelihood of receiving the right product and return unwanted items [175]. For this reason, customers are more likely to purchase products from fashion companies that provide convenient and free return policies, and fashion companies use lenient return policies to boost their sales nowadays [93, 21, 127, 158]. However, these policies normalize over-ordering behavior and drive opportunistic returns, as customers might 'just order' a product to see it at home [200, 89]. These factors contribute to the higher numbers of returns in the fashion industry. Fashion companies do not prefer adopting a restrictive return policy as it might impact their businesses. Therefore, changing policies' leniency is not a preferred method of reducing the environmental impact of returns in fashion [194, 175, 93, 101].

2.2. How the process of product returns works

A high-over definition of the reverse process is given by [45], consisting of collection, inspection/selection/sorting, recovery, and redistribution. [15] defines this process as (p.490-491): "customer return request, return logistics, processing and sortation, inventory control, repair and refurbishment, and final disposition." From this perspective, the returns process is linear and can be seen as a singular phenomenon. However, several return methods are available, so this simplicity no longer holds [14]. Therefore, four phases are distinguished in the product return process: return preparation, collection, processing and handling of returns, and product recovery and disposition, which is visualized in Figure 2.1. Within each stage, consideration is given to how a product can be returned. Each process phase has various logistic activities that must be considered to evaluate the impact created in the return process [145, 51].

In short, the return is first prepared by the customer. The customer must request the return, choose a return method, and ensure the product's packaging is for safe transport. The return method determines how the collection transports the product from the customer to the final recovery point. This final recovery point is the brick-and-mortar store or the local warehouse. Transport networks for forward deliveries are commonly used for return transportation [40, 78]. A vehicle journey needs to be designed for each return method, and consideration must be given to factors including the integration of deliveries and pick-ups, the vehicle fleet, the combination level, and whether the split collection is acceptable. A general vehicle routing model can be used to model the reverse network [18].

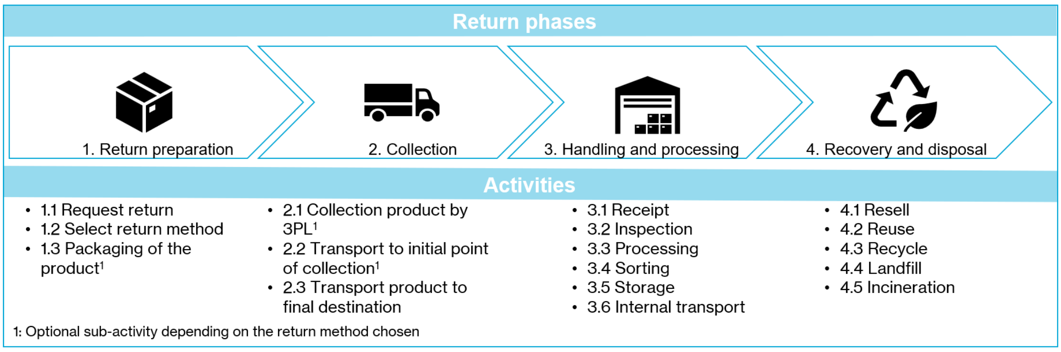

Figure 2.1: Return processes and sub-activities, adapted from [42]

According to experts, when a product is collected and has arrived at the brick-and-mortar store, it can be processed and handled in-store to be resold or transported to the warehouse. Warehousing activities are receipt, inspection/processing/sorting, storage, and internal transport [45, 174, 15]. First, it is checked whether the product meets the conditions for a return. If this is completed, product inspection occurs, and the product is registered. Following, the product is moved to the temporary storage [103].

E-commerce has shifted warehouse requirements, as they need to resist higher and more fluctuating volumes of returns [164, 103, 42]. Also, orders are single-picked and handled rather than in batches [103]. The area in a warehouse dedicated to returns differs per (type of) retailer [42]. The number of product returns in the fashion industry is substantial compared to other industries. Therefore, it is common for fashion retailers to have a separate area for return receipts and storage facilities at the warehouses [42, 45]. It is also possible to have a separate warehouse for returns- and on orders when the retailers' warehouse capacity is insufficient [96]. Those separate centers are mostly managed by Third Party Logistics Provider (3PL), who specialize in return handling and improving efficiency in the process. In a case study with different e-commerce companies of [96], it was found that less than 20% of the surveyed companies used separate centers for their return handling 2016.

After the product is inspected, the product recovery strategy is chosen. High-quality items can be resold quickly through redistribution, resale, and reuse. Reprocessing is required for defective products, and procedures include recycling, mending, dumping in a landfill, and burning [45, 107, 5]. The recovery decision of a company is based on several criteria, including the cost, the product market value, added value of recovery, and the type of product [107]. Reselling does not require fixing or replacing activities and often only requires repackaging the products before storing them in storage [107, 5]. Recovery, repair, and recycling disposition strategies of the products aim to get as much return of the product as possible. Typically for fashion e-commerce, high returns are experienced although these products are not damaged or show defects [124]. Most of these products are resold at (secondary or outlet) markets or sent to landfills or incineration [36, 5]. Currently, the share of recycled clothes worldwide is very low and below 1% [52]. An expert with industry knowledge mentions that this is also true for the recycling rates of clothes in the Netherlands.

2.3. How a customer can return a product

Generally, fashion companies use three return methods: in-store returns, drop-off at collection points, and home pick-up. The availability of a return method depends on the type of retailer where a product is purchased. Purely brick-and-mortar retailers solely offer in-store options for handing in a return. Pure online retailers have no physical store and only offer returns services by dropping off packages at collection points or home pick-up. Omnichannel retailers provide all of the above, as they are active in physical stores and online channels. A short elaboration is given for each return method:

- In-store returns: Customers must return the product to the physical store. Returns will be processed in-store and put on the shelves in-store, or a vehicle will pick up the return to transport it to the warehouse.
- Home pick-up returns: The company offers a home pick-up service, and a pick-up moment is scheduled with the customer. The customer must repack the product for transport, which is picked up at home by a 3PL. The 3PL service will transport the package to the final destination.
- Collection point returns: Customers must repack the product and bring it to a collection point. The company offers a set of alternatives for collection points with different 3PL companies (i.e., UPS, PostNL, and DHL in the Netherlands). The collection points can be locker systems, kiosks, office stores, or other stores that offer this additional mail service. The 3PL picks up the package from the collection point and transports it to the final destination. The number of collection points available to customers depends on the density of residents where they want to drop off the package [152, 30].

2.4. How a product return creates environmental impact

This section gives insight into the environmental impact created by product returns and how this is measured. This is done by analyzing the four phases of product returns: return preparation, collection, processing and handling, and product recovery and disposition. Within each stage, consideration is given to how a product can be returned, which factors should be considered for the environmental impact, and how the environmental impact can be measured. A high-over visualization of this is presented in Figure 2.2, where the boxes in red represent the activities that create environmental impact in each phase. First, it is elaborated on how the environmental impact is measured in subsection 2.4.1, followed by a comprehensive description of the activities within each phase and how they can be measured.

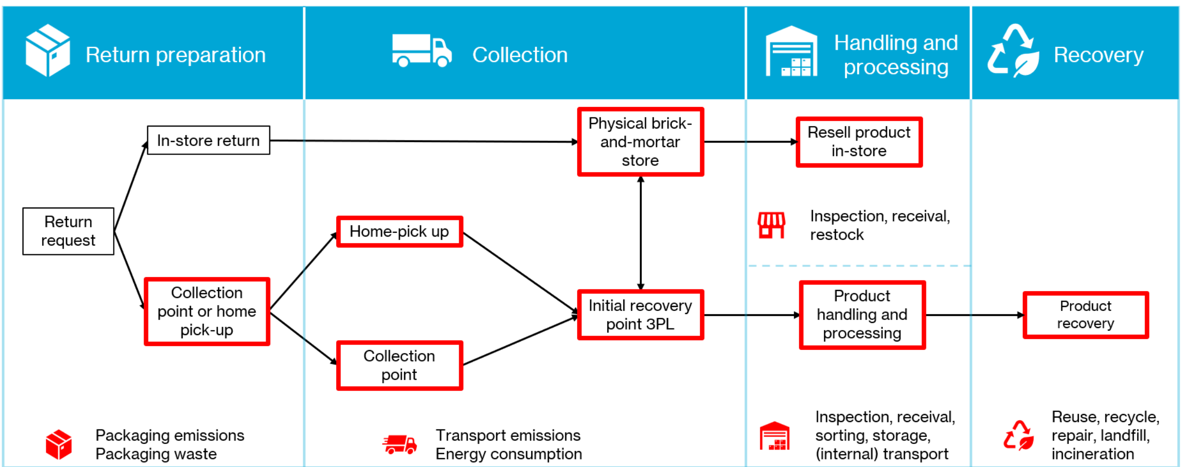

Figure 2.2: Flow chart of the process of product returns, considering sources of emissions and return methods, source: (Author)

2.4.1. How the environmental impact is measured

This research intends to assess the environmental impact of product returns by measuring the Greenhouse Gas (GHG) emissions. The literature shows several valuable tools to evaluate environmental impact, including the GHG Protocol and the Life Cycle Assessment (LCA). The focus of this research is to measure the GHG emissions that arise in the different activities involved in the process of product returns for a company. Activities before the return request are excluded from this research scope. Therefore, a measurement method should focus on assessing the impact of specific activities and processes rather than all the stages in a product's life. Additionally, this environmental assessment focuses solely on the GHG emissions and not other environmental factors such as water usage or resource depletion.

The LCA is a well-applicable method when measuring a more comprehensive set of environmental factors and evaluating the effect of a product throughout its entire life cycle [130]. The GHG Protocol can be more useful when specific activities and GHG emissions need to be measured. Also, the GHG Protocol is commonly used as an accounting tool at the company level for activities in its value chain [83].

Taking these aspects into account, the GHG Protocol will be used to measure the GHG emissions of the activities involved in the process of product returns. Examples of the usage of this method to assess GHG emissions can be found in the research of [76] and [162]. The GHG Protocol is a recognized tool by the European Union (EU) for measuring and reporting GHG emissions of different activities. It provides a standardized methodology for measuring scope 1, 2, and 3 emissions. In Scopes 1 and 2, emissions are measured from sources the company owns [58]. Scope 3 emissions produced by downstream and upstream activities in the company's value stream, such as outsourced transport, distribution, retail, storage, and end-of-life treatments of products [84, 83].

The GHG Protocol uses Emisison factor (EF)s to calculate the GHG emissions. These EFs should be retrieved from peer-reviewed, widely accepted databases consistent with GHG Protocol standards, such as 3EID, Defra, Ecoinvent, or IDEA. These are mostly life cycle databases, where the EF are calculated based on the whole life cycle or cradle-to-gate emissions [88]. Other sources that can be used to obtain EF data are from governments or academic studies.

2.4.2. Phase I. Return preparation

In the fashion industry, packaging significantly contributes to GHG emissions [191, 118, 102, 16]. The reason for this is twofold. First, products are packaged individually to ensure that they are transported safely. Second, only a tiny percentage of customers use the original package when returning a product. Nearly 80% of the customers do not use the original box of the product when they return it [32, 191]. This implies that for this fraction of customers, product packaging doubles when they return [191], generating additional waste.

The packaging is needed if the customer selects an online return method (i.e., return through a collection point or home pick-up) or when the product gets transported from the brick-and-mortar store to the warehouse. This additional packaging waste needs to be treated by the company at the warehouse [102, 118, 188]. In the apparel industry, transit packaging is used. This can be mainly classified into paper and plastic packaging materials for e-commerce [195, 54]. Of these packaging types, cardboard boxes are the most widely used option in e-commerce in particular [33, 32, 102]. An expert with industry knowledge of fashion warehouse operations also confirms this. Cardboard packaging ensures the safe transportation of the product and is also relatively low-cost and lightweight. However, cardboard boxes are primarily designed for single-use only, and the emissions created by cardboard packaging are 60% higher than plastic packaging bags [191, 16]. This is mainly because a larger volume of cardboard must be used compared to plastic for one package (i.e., 100-gram cardboard against 8-gram plastic per package [188]) and the re-usability of plastic bags compared to single-use cardboard [16].

To calculate the GHG emissions of packaging, insight into the type of packaging material used and the package size is needed. A material-specific EF can be multiplied by the mass of a parcel to determine the kgCO2eq-emissions of packaging, as seen in Equation 2.1 [84, 176].

$$\text{Packaging usage emissions} = \mathrm{m} * EF_{\text{packaging material}} \tag{2.1}$$

The additional product packaging waste needs to be considered for the environmental assessment of a company [84] and is relevant as Europe's total packaging waste is growing steeper than GDP [68]. Waste treatments are recycling, incineration, or disposal to landfill [176]. The emissions of packaging waste can be determined by the total mass of packaging material multiplied by the waste-treatment-specific EF, see Equation 2.2 [84, 176].

$$\text{Packaging waste emissions} = \text{m} * EF_{\text{waste treatement}} \tag{2.2}$$

Depending on whether the EF selected is based on the entire life cycle, it is sufficient only to include the waste method for the specific type of packaging to determine the GHG emissions, as double counting of emissions must be avoided [84].

Summary
Packaging emissions are created to ensure safe transportation, which is needed when a customer returns by home pick-up or collection point or when the product gets transported from the brick-and-mortar store to the warehouse. Cardboard boxes and plastic polybags are the most common packaging material. Packaging emissions consist of usage and waste emissions. The magnitude of the usage emissions depends on the type of packaging material, the mass of the packaging, and whether or not a customer reuses the packaging for their return [84, 176]. The packaging waste emissions depend on the waste treatment chosen, the type of packaging material, and the mass [84, 176].

2.4.3. Phase II. Collection

There can be two transport activities considered in the transport network for returns. First is the short-haul movement between the customer and the (if present) initial recovery point (i.e., store, collection point). Second, is the product's transportation from the initial recovery point to the final destination. A general overview of the transport activities and recovery points involved in the return process is visualized in Figure 2.3. The transport activity and measurement approach are further elaborated for every return method.

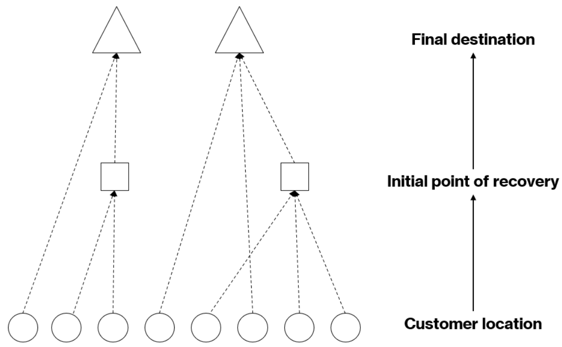

Figure 2.3: Transport structure general overview, adapted from [77]

Environmental assessment models for reverse transport streams are currently designed concerning the condition that the same method is used to deliver and pick up a product. By doing so, it is assumed that the GHG emissions of the delivery are roughly the same as the pick-up transport order [40]. However, this condition does not always hold as customers can choose another return method than their delivery method, increasing the complexity for determination of the transport emissions. The transport emissions should be calculated separately for each return method to accurately assess the emissions [51, 22, 118]. According to [78], returns can, in many cases, be implemented in the forward distribution networks. This means the same logistic network designs can be used for return logistics. The methods for calculating transport emissions for deliveries can be adapted and used to determine the emissions of the different return methods [40].

Further, this research does not consider integrations of deliveries and return requests in a vehicle journey [77]. Although integration of these streams is sometimes employed, combining these pick-up and delivery tasks can be complex because of vehicle loading constraints. This may lead to situations where a vehicle first makes a delivery round, and after all the deliveries are made, it collects the returned products that are returned [77, 45]. Also, it might be that a different warehouse for collection and delivery and another vehicle fleet is used, which means that integration is not likely [78]. The collection and delivery tasks are therefore treated separately in this research. The trip purpose of the vehicles is to pick up the returned items and transport them back to the final destination. A general vehicle routing problem with a single warehouse is assumed to be the underlying transport model, in which several conditions are respected. In this transport model, the return requests are represented by demand nodes n, and the arcs represent the actual distance d_{ij}

from node i to node j. The vehicle departs at the warehouse and ends its journey at the same location. The origin and destination are represented by nodes *0* and *n+1*. The capacity of the vehicle or time limitations limits the vehicle's journey. Additionally, it is assumed that a customer's request must be served in one visit [35, 192, 45].

Two methods for determining transport emissions on a company's vehicle journey are based on the fuel used or the distance driven [84, 85]. The former method calculates a vehicle's fuel consumption and multiplies this with fuel-specific EFs to measure the GHG emissions. The latter method multiplies the total travel distance by a specific type of modality, the transported mass, and an EF [84]. The suitability of an approach depends on several factors, including the required detail, the context of the analysis, and the availability of data to determine the emissions. The transport emissions are measured for each return method and elaborated further below.

Return alternative 1. Brick-and-mortar store returns

The customer must take the product back to the brick-and-mortar store. The GHG emissions created depend on the type of modality chosen by the customer and the distance traveled. After the returned products have arrived at the store, returns can either be handled and resold there, or they will be transported to the retailer's warehouse. If the decision is made to move the product to the warehouse, additional transport is needed [42].

To determine the GHG emissions from transport for a product returned in a physical store, the whole journey of a customer is considered. It is assumed that returning is the purpose of the trip; therefore, the transport emissions from the customer to the store and returning home are included in this assessment [199, 118, 51, 24]. Gathering accurate data on the amount of fuel a customer uses can be challenging and not feasible within the limited scope of this research. Therefore, the distance approach is likely more suitable than the fuel-based to determine transport emissions. The total distance is determined by the kilometers traveled from the customer's location to the closest store location and back [84]. The following equation gives the best approximation of the transportation emissions of this return method, which is adapted from [40].

$$\text{Transport emissions} = \sum d * m * EF_{modality} \tag{2.3}$$

Here, d represents the distance of the customers' location to the brick-and-mortar store and the distance from the store back home in kilometers. A specific EF EF is assigned based on the modality. It can be difficult to obtain accurate data on a customer's specific modality, and it is common to make assumptions to this end [199, 118, 51].

For the optional transport activity from the store to the warehouse, the store is treated as a demand node in the transport model [40]. The transport emissions for this journey are added to the transport emissions of the customer trip.

Summary

Transport emissions depend on the customer's trip to the store and back home [199, 118, 51, 24]. If the decision is made to transport the product to the warehouse, additional transport emissions are created, depending on the distance traveled, product mass, and vehicle energy consumption. Considering the scope and availability of data in this research, the best approximation for measuring transport emissions is the distance method.

Return alternative 2. Home pick-up

The transport network structure of the home pick-up service depends on the specific locations where a customer requests a return. Transportation services must include this pick-up point in their vehicle journey to meet demand. The number of requests that can be served in one vehicle journey depends on the capacity of the vehicle and time constraints. The transport emissions created when a product is picked up at the customer's door depend on the modality used to fulfill this service, the type of vehicle journey (consolidated pick-up and delivery or separated journey), the number of stops, and the distance between the customers' location and the final destination [84, 40]. According to expert consultation, the decision can be made at the distribution center to transfer the product to a brick-and-mortar store or a warehouse.

It is considered that each demand node corresponds to one return request for a home-pick up. So, the number of nodes equals the number of return requests. The requests are represented by the set P demand nodes with *1,...,n* requests. The distance d_{ij} represents the distance from pick-up point i to pick-up point j. Nodes *0* and $n+1$ represent the recovery point [46, 35, 192, 40]. The Vehicle Routing Problem with a single depot as formulated by [46, 35, 192] and the calculation of transport emissions on a pick-up route as proposed by [40] is adapted to the following equation:

$$\text{Transport emissions} = (\sum_{(i,j)\in P} d_{ij} + d_{0,i} + d_{j,n+1}) * m * EF_{modality} \tag{2.4}$$

Here, a constant vehicle fuel consumption is assumed [40]. A customer might return multiple items within one return request, so the number of nodes equals the number of requests. [118] proposes a simplified calculation when there is a lack of data on the subsequent coordinates of the nodes, where the average distance of 50 km per parcel is assumed for a pick-up route, which can be multiplied by the mass of the parcel and the modality-specific EF to determine the transport emissions of this pick-up journey.

Next, Equation 2.3 is used to calculate the emissions between the initial point of recovery and the final recovery point, as this long-haul transportation is performed by another modality [84]. These vehicle characteristics need to be taken into account for this trip. The total emissions per product return using pick-up methods can be measured by a summation of the emissions generated by both trips.

Summary

Based on the locations of the pick-up requests, a vehicle journey is constructed from the pickup point to the initial recovery point. The total distance traveled, and the mass should be measured and multiplied by an EF for the modality used on this vehicle journey [40]. For the long-haul trip between the initial point of recovery and the product's final destination, the distance method should be applied, considering the vehicle characteristics performing that trip [84].

Return alternative 3. Collection point returns

Three transport activities are distinguished to determine the transport emissions when using collection points for returns. These are the customer's transport to the collection point, from the collection point to the initial recovery point, and the warehouse or brick-and-mortar store. In the Netherlands, collection points are relatively well accessible [152, 30]. Therefore, it is assumed that customers only need to travel short distances when they bring their product to a collection point. The most preferred modalities for these short distances are walking, PT, or cycling [28]. The transport emissions for this activity can be determined similarly to the in-store transport emissions using the Equation 2.3. Thus, for this part of the transport assignment, the customer's location, the collection point, the mass of the product, and their choice of modality need to be considered [84].

Second, the product is transported from the collection point to the initial recovery point by a vehicle of a 3PL. The vehicle journey starts at the departure of the distribution center, visiting several collection points within a specified distance and maximum vehicle payload range and returning to the recovery point. Vehicle journey constraints are the vehicle's maximum payload and the operating time [45, 40].

The emissions for this journey can be calculated by adapting Equation 2.4, where a constant fuel consumption per traveled kilometer is assumed [40]. The distance d_{ij} represents the distance from collection point i to j. Nodes *0* and *k + 1* represent the distribution center. k represents the number of collection points. The number of requests served per collection point should be summed up to determine the total number of requests handled per journey.

$$\text{Transport emissions} = (\sum_{(i,j)\in C} d_{ij} + d_{0,i} + d_{j,k+1}) * m * EF_{modality} \tag{2.5}$$

The emissions generated by transport from the initial recovery point to the final destination are calculated using the distance method, considering the specific vehicle characteristics for that trip [84]. The total emissions per product return can be measured by a summation of the emissions generated by the three transport activities.

Summary

Transport emissions are measured by distinguishing three transport activities. First, the transport of the customer to the collection point and emissions are created depending on the modality, product mass, and distance traveled. Second, the product is collected at the collection point by a 3PL as part of a vehicle journey. The transport emissions of this journey depending on the distance, modality used, the number of collection points served in that journey, and vehicle characteristics. Third, the created emissions from transporting the initial recovery point (i..e, distribution center) to the final destination should be considered and measured by the distance method [84].

2.4.4. Phase III. Product handling and processing

Return handling at warehouses is critical in the return process and has become essential to warehousing operations [103]. Four sub-activities can be specified: receipt, inspection/processing/sorting, storage, and internal transport [45, 174, 15]. The activities are visualized in Figure 2.4.

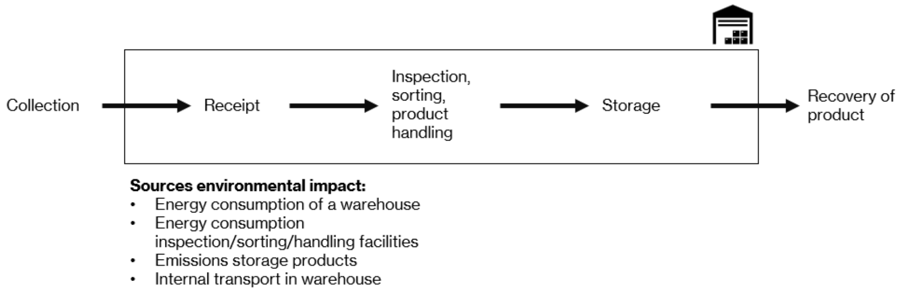

Figure 2.4: Product handling and processing process, adapted from [45, 42]

First, the product arrives at the designated location in the warehouse and is checked to determine whether the product meets the conditions for a return. If this is the case, the product inspection takes place, and the product is registered. Following, the product is moved to the storage area in the warehouse dedicated to returns [103]. According to an expert with knowledge of fashion warehouses, the storage of a product takes up approximately 3-5 days before it will be reallocated (redistributed or sent for processing recovery). Different factors must be considered when looking at the environmental performance of the operation processes in a warehouse. First of all, the energy consumption of the warehouse must be considered. An environmental impact study of warehousing of [154] links the size of the warehouse to energy consumption and the geographical location of the warehouse. The main contributors to warehouse energy consumption are the lighting, heating, and cooling of the building [118, 154]. The literature proposes detailed calculation methods for determining GHG emissions per fuel and usage type. However, this level of detail is unknown as warehouse managers mainly have information on the total energy consumed at the warehouse by fuel type [75]. Therefore, this research uses a more aggregated measurement approach to determine the GHG emissions generated in the warehouse, which is derived from [84, 83]. Here, the total electricity consumed at the warehouse is multiplied by a specific EF. The fuel consumed in the warehouse is also multiplied by an EF. The electricity and fuel consumption are measured over a particular period, for example, a year or quarter [75]. These values must be in the same unit of measurement. The total warehouse emissions are divided by the number of products handled during the considered period, represented by n in Equation 2.6.

$$\text{Warehouse emissions} = \frac{(\sum \text{fuel consumed} * EF_{fuel}) + (\sum \text{electricity consumed} * EF_{electricity})}{n} \tag{2.6}$$

Additionally, material handling equipment is needed to process and move the products between areas in the warehouse. The equipment in a warehouse is also a contributor that should be considered in the environmental assessment of product handling and processing emissions [154]. There is fixed equipment like conveyor belts and mobile equipment like trucks and forklifts [154]. Based on this nature, different factors should be considered for the environmental assessment. Mobile equipment's generated emissions and consumed energy can be determined based on the average distance traveled and the equipment characteristics [90, 75]. For fixed-handling equipment like conveyor belts, energy consumption is primarily associated with the size of the warehouse, the hours of operation, and the equipment characteristics [154]. The input data for these emissions are likely not known on a product level, according to a warehouse expert, so therefore the equipment emissions should be determined for a whole year, considering the fuel and electricity consumed. This number should be divided by the number of products served with this equipment to derive the GHG emissions on the product level. The GHG emissions can be determined by Equation 2.7, where n represents the number of products handled over the considered year, adapted from [84].

$$\text{Equipment emissions} = \frac{(\sum \text{fuel consumed} * EF_{fuel}) + (\sum \text{electricity consumed} * EF_{electricity})}{n} \quad (2.7)$$

When a product is returned through an in-store return alternative or redistributed to the store, the product is handled in-store. The environmental impact should be considered for receiving, processing, handling, and restocking the product return at the store. The energy consumption of the brick-and-mortar store should be analyzed and converted to GHG emissions by an appropriate EF. The energy consumption can be generally approximated based on the invoices and further specified by the store size, location, and the energy rating [118]. Based on the average time a product spends at the store, and the number of products handled in the store over time, the in-store emissions allocated to a product return can be determined [84].

Summary

The total warehouse emissions can be determined by the fuel and electricity consumed, which are converted to GHG emissions by a specific EF. In addition, internal transport and the energy used by warehouse equipment for handling facilities must be considered. There are two types of equipment, which are fixed and mobile [154]. The energy consumption of the former depends on the kind of equipment, size of the warehouse, and operation time. For the latter, energy consumption can be measured as a function of the distance traveled, equipment type, and characteristics. The total emissions must be divided by the total number of products served. Further, products can also be handled, received, and processed at a brick-and-mortar store. Here, the energy consumption of the store needs to be considered.

2.4.5. Phase IV. Recovery and disposition of products

The final phase in product returns is the recovery and disposition of products. High-quality items can be resold quickly through resale and reuse. Reprocessing is needed for imperfect products, and procedures include recycling, repair, remanufacturing, landfill disposal, and incineration [45, 107, 5, 77]. Recovery can be categorized as direct and process recovery, where the latter means reprocessing activities are needed [45]. The type of recovery and disposition strategy chosen affects the created GHG emissions in this stage [15, 84, 68].

The calculation of GHG emissions for this phase of the return process is defined for the chosen recovery method. In Equation 2.8, a formulation is given where the waste treatment EF refers to the chosen recovery strategy for the product [84].

$$\text{Recovery emissions} = \text{m} * EF_{\text{waste treatment}} \quad (2.8)$$

Summary

The magnitude of the environmental impact of a product recovery depends on the chosen strategy. Products can be resold, repaired, recycled, remanufactured, or sent to incineration or landfills [45, 107, 5, 77]. The environmental impact can be measured by the mass of a product and the specific EF for the chosen waste strategy [84].

2.5. How a product return creates costs

A breakdown of the significant cost factors involved in a company's product returns process is looked into, as well as how these cost factors can be measured. According to an industry expert, this should be done according to the theory of activity-based costing, as fashion companies prefer this method in practice. This means that each activity in the return process needs to be considered for the cost estimation. Also, the different return methods affect the costs [117]. This research only includes the costs made in the process of a product return for a company by performing the return activities. Costing of return-related activities includes transportation, labor, handling equipment, disposition, and storage of the products and packaging [89, 114]. Two independent experts confirm these cost activities for returns.

Transport costs

This metric captures the costs for transporting the product from the origin to its final destination (i.e., warehouse or brick-and-mortar store). Different factors must be considered for each return method, such as the transport modality, distance traveled, weight, and product size [89]. Also, the transport is usually outsourced to a 3PL but can be self-executed, affecting the cost structure [42]. Brick-and-mortar returns only generate transport costs for a company when the decision is made not to resell the product in-store and transport it to the warehouse. This cost metric can be measured using the distance-driven method or the fuel consumed

[45]. Factors such as leased vehicles, transport planning, and service costs should also be considered. A calculation can be made based on the distance driven, the vehicle load, the mass of the product, and fixed- and variable modality costs, as presented in Equation 2.9 [187]. Here the c_{charge} includes modality-specific factors expressed per ton-km distance driven.

$$C_{\text{transport}} = \sum d * c_{charge} * m \tag{2.9}$$

[89] proposes another measurement approach for the transport costs per item at collection points, independent from the distance driven, where a transport fee based on the return method is proposed using Equation 2.10. Here, r is the return rate, $c_{\text{tra}}(q_k)$ the transport fee for a parcel with a certain weight, c_{cus} is the optional fee the company charges the customer for a return, and k the number of items returned in one parcel [89].

$$C_{\text{transport}} = \sum_{k=1}^{k-1} \frac{r\delta_n(q_k)}{k} * (c_{\text{tra}}(q_k) - c_{\text{cus}}) \tag{2.10}$$

Warehouse space costs

A major source of costs in product returns is related to warehousing activities [42]. The activities that should be considered are product receipt, handling, inspection, holding, and storage, which all require space at the warehouse. These costs can be calculated by estimating the proportion of the used space dedicated to returns from the total warehouse area. Based on this estimated proportion, the costs can be determined based on the total warehouse space costs [42]. This can be determined based on the area for return handling and the warehouse rental cost [42]. The calculated amount should be divided by the total number of returns to derive the warehouse space cost per return item.

Warehouse equipment costs

These factors refer to costs for the equipment needed to process product returns (e.g., forklifts, sorting systems, conveyors, and packaging machines). In this metric, equipment depreciation is captured when equipment is not leased. Equipment costs per return can be measured by dividing the total equipment costs by the number of returns handled over a time period.

Warehouse labor costs

Labor costs are expenses associated with the human resources needed in product returns handling, which is quite intensive for returns. Activities include receiving, inspecting, and restocking products [89]. The product return labor cost on an annual basis is the sum of these fees [89]. Additionally, this metric should include any overhead expenses and investments like training or other employee benefits in this metric [42]. The calculation of [89] is adapted to Equation 2.11, which expresses the total labor costs per returned item:

$$C_{\text{labor}} = c_{\text{res}} + c_{\text{rec}} + c_{\text{overh}} \tag{2.11}$$

Here, c_{res} is the costs for inspection and restocking per product, c_{rec} is the cost of receiving per item, and c_{overh} is the overhead expenses per product [89, 42].

Product recovery and disposal costs

This metric refers to the expenses of products that cannot be resold anymore due to a return and sent to a landfill. The recovery costs per return are calculated by the mass of the returned product, the recovery charge per kg, and optional transport charges. The charge depends on the type of recovery treatment, the mass of the product, and the country of recovery [69, 53].

$$C_{\text{recovery}} = m * (c_{\text{charge}} + c_{\text{tra}}) \tag{2.12}$$

Where m is the mass of the product, c_{charge} is the charge for landfill or disposition, and c_{tra} is the optional transport cost to the recovery facility.

Packaging recovery and disposal costs

Each product arrives at the warehouse with packaging material to ensure safe transportation. The company must handle this waste by choosing a waste treatment. The waste treatment chosen is either recycling, incineration, or landfill. Governmental charges are associated with landfill and incineration, which come at the cost of a company [94]. The created costs depend on the type of waste treatment selected, the packaging mass, the packaging material, and additional recovery or disposal charges [39].

Brick-and-mortar store space costs

Operating costs of the physical store should be considered for in-store returns. According to an expert, the most significant cost factor is the leasing costs of the store. Usually, these leasing costs can be derived from the annual financial statement. The costs per unit product can be estimated by obtaining the total number of products handled at the store over a certain period.

Brick-and-mortar store labor costs

Labor costs are considered in this metric, including receiving, inspecting, and restocking the returned products in-store. Additionally, the overhead employee expenses should be considered in this cost metric. The same formulation as Equation 2.11 can be used to derive a number for this metric, adapted from [89]. Another approach for measuring this cost metric can be determined by the hourly labor cost multiplied by the duration of a task [189], where the employee overhead expenses also should be considered.

Summary

Costs involved in the product return process for a company can be broken down into several factors using the theory of activity costing. The following cost factors need to be included in the economic evaluation: transportation costs, warehouse space utilization costs, material handling equipment costs, labor costs, product recovery and disposal costs, brick-and-mortar store space costs, and brick-and-mortar store labor costs.

2.6. Main findings chapter 2

In this chapter, SQ1, SQ2, and SQ3 are answered. First, the process of product returns in the fashion industry is investigated, which consists of a return request, collection and transportation, handling and processing at the warehouse, and product recovery and disposal. An answer is formed to SQ1: *What does the fashion industry's product return flow look like?*

This overarching SQ is addressed by SQ1a) *Which returns methods are available in the fashion industry?* and SQ1b) *What are the logistic activities involved in the product return process, and how do they differ depending on the chosen return method?*. The return process starts when the customer requests a return and selects a method to process this request, which can be: by brick-and-mortar store return, drop-off at a collection point, or by home pick-up. The availability of the return methods for a customer depends on whether the retailer offers this service. The customer must re-pack the product for safe transport if a home pick-up or collection point is chosen as the return method. Next, the product is collected and transported from the customer to the final recovery destination, either the warehouse or the brick-and-mortar store. How this transport is arranged depends on the return method chosen. Products with the brick-and-mortar store as the final destination are restocked and resold. If the product is sent to the warehouse, it will be received, handled, inspected, and temporarily stored until a decision is made on how to recover it. The recovery choice determines if the product gets resold, recycled, repaired, remanufactured, or disposed to landfills or incineration [45]. After the recovery activity is performed, the process of returns is finished. This process is visualized in Figure 2.1.

This chapter has also mapped the factors that should be considered for an environmental assessment of product returns and how these can be measured.

SQ2. *How can the environmental impact of the various logistic activities involved in product returns be assessed?*

The environmental impact is measured using EF specified for each activity to measure the GHG emissions created per returned item. The following elements were essential for assessing the environmental impact of product returns: packaging material, packaging waste treatment, transportation, warehousing, storage, equipment usage, product recovery, and brick-and-mortar activities. To assess the environmental impact of packaging and transportation, it is necessary to consider the chosen return method [51]. Figure 2.2 highlights in red the activities where environmental impact is created and how the return method affects this assessment. These insights are obtained by answering SQ2a) *What are the key factors that should be considered when assessing the environmental impact of these logistic activities?* and SQ2b) *How can the environmental impact of these factors be measured?*

Next, this chapter has provided a breakdown of the significant cost factors of product returns that should be included in the economic assessment for a fashion company. With this information, the third sub-research question is answered.

SQ3: *How can the economic impact of the various logistic activities involved in product returns be assessed?*

This SQ is addressed by examining SQ3a) *What economic factors should be considered for assessing the economic impact of these logistic activities?* and SQ3b) *How can the cost of these factors be measured?*. Through the theory of activity-based costing, supplemented with literature and expert consultation, the following costs are identified: transport, warehouse space utilization, equipment, labor, product- and packaging recovery and disposal, storage, in-store space utilization, and in-store product processing. With exceptions made for the transport and recovery costs, measured per kg return item, these costs are measured annually and expressed in euros per returned item.

3
Methodology

This chapter presents the methodology used in this research. First, an introduction will be given to performance measurement, which is the theoretical foundation for the method. The performance will be measured using indicators aggregated into a Composite Indicator (CI), elaborated on in section 3.2. Once understanding is created of the concept of a CI, the steps to construct a CI are explained in section 3.3 followed by construction guidelines in section 3.4. The measured performance will be compared relatively to a benchmark, as explained in section 3.5. In this chapter, SQ4a) *How can companies use a CI to assess their performance on multiple dimensions?* and SQ4b) *Which steps need to be performed to construct a CI for an assessment on multiple dimensions?* will be answered.

3.1. Why performance should be measured

This study aims to measure, compare, and reflect on the company's performance of product returns on both environmental and economic dimensions. The chosen way to fulfill this objective is by company performance measurement. A definition of *performance measurement* is "the process of quantifying the efficiency and effectiveness of an action" [149, 136]. The choice of performance measurement for achieving the objectives of this research is threefold. First, performance measurement assists companies with the identification of potential areas for improvement [116, 92]. Fashion companies want to reduce the Greenhouse Gas (GHG) impact caused by product returns. Still, it is essential first to determine where the problem lies to specify any actions to correct it. Second, company performance measurement assists a company in tracking its progress in achieving particular goals [203, 125]. In the context of this research, fashion companies aim to lower their GHG footprint, which is a continuous process, and efforts and progress made by the companies should be measured and monitored relative to the goal of meeting their targets. Third, performance measurement is a suitable tool to communicate, motivate, and create awareness with involved actors (i.e., employees, customers, stakeholders) on specific targets or topics [113, 125]. Fashion customers increasingly demand more transparency, information, and understanding of the environmental impact of their choices to make more sustainable decisions. Fashion companies can use performance measurement to create knowledge and information to encourage customers to make better and more conscious decisions. These transparent insights can also be communicated with, for example, governments, as governments are likely to require environmental performance reporting of companies [62].

The added value of company performance measurement is greatest when it reflects reality. Previously, company measurement frameworks mainly assessed performance from a financial perspective as this was deemed the primary indicator of success [203, 2]. As the importance of sustainability and environmental issues has grown, companies need to measure, consider, report, and manage their environmental impact as well [149, 179, 136]. To accomplish environmental and performance improvements, knowledge of the factors that contribute to this environmental impact should be created for companies [205]. A shift towards more integrated measurement frameworks that include, besides economic performance also, environmental performances of companies is expected and introduced by [203].

3.2. How performance is measured by indicators

The performance of a process, system, or activity can be measured using indicators [206]. An indicator is a measure that assesses, analyses, and monitors quantitative or qualitative data on specified topics and breaks it down into small pieces of information [153], which provides information for decision makers [134, 206, 169]. A combination of indicators with multiple dimensions (i.e., environmental and economic) should be considered in performance measurement to provide an overall picture of the situation. This cannot be done with individual indicators because they only cover a single aspect or dimension of the measured topic. When comparing a more extensive set of individual indicators, complexity issues arise that complicate interpretation and comparison [138]. Therefore, a broader set of indicators should be considered that covers the considered dimensions and presents this in a well-structured way. This can be done by a CI.

A CI can give a more comprehensive view of the performance while considering multiple dimensions. Developing a CI is an essential aspect of performance measurement [203, 208, 8]. CI aggregate multiple indicators into a single measure, thereby presenting large amounts of complex information in a simplified way [206, 196]. They can mathematically combine individual indicators with different units of measurement, and no standard way to weigh [179, 134]. The created CI can be used to quantify, measure, evaluate, and compare the performance of a set of indicators on multiple dimensions (see [138, 207, 203, 206]). CIs can be used to track progress, identify shortcomings, provide information, and raise awareness on the topic being measured [133].

The use of CIs has gained popularity and is commonly used in a variety of sectors as a way to provide a comprehensive picture of the performance. However, CIs are also subject to criticism because of some limitations, including complexity, subjectivity, interpretation issues, and missing data. Some steps are exposed to subjectivity during the construction of the CI because decisions and assumptions need to be made [133, 206]. This may lead to potential biases in the results. This may be amplified by misinterpretation issues that lead to misleading information [134]. This can be accounted for by systematically evaluating, reflecting, and reporting the choices that are made during the construction of the CI, thereby increasing transparency and improving the reliability of the CI [134, 133]. In conclusion, there are pros and cons to using the CIs, but if appropriately used, CIs are valuable tools for performance measurement. It is essential to pay awareness to the previously mentioned risks and limitations of the CI by systematically reflecting on the choices to improve transparency and reliability.

3.3. How a Composite Indicator can be constructed

This section discusses the construction of a CI. This construction will be done according to the guidelines of [134]. Typically, five subsequent phases in constructing the CI are visualized in figure 3.1. First, the objectives and scope of the CI are defined. Next, the indicators are selected, normalized, weighted, aggregated, and evaluated [203, 10, 87]. For each phase, a short checklist is given on what should be finished before starting the next phase.

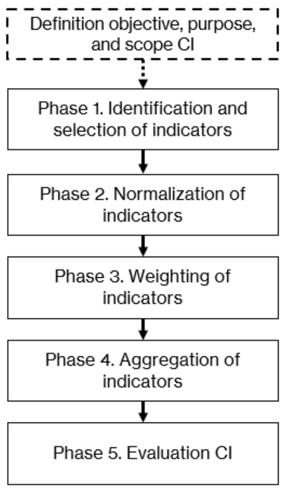

Figure 3.1: Construction of a CI, adapted from [203, 10]

3.3.1. Phase 1. Identification and selection of indicators

The first step in constructing a CI is identifying and selecting all relevant indicators to measure the system's performance or action. To ensure that all relevant indicators are included [134] recommends designing a theoretical framework. This framework should be based on the objectives and scope of the CI, so the indicators represent the various sub-activities that should be measured [134]. The theoretical framework can be used as a final check for the set of indicators, selecting the underlying criteria, and improving understanding of this problem on multiple dimensions [87, 134]. Most of the indicators can be found through a literature review. Further, expert consultation, interviews, surveys, the Delphi technique, and Content analysis can be used to extract additional information [203].

By the end of this phase, a clear overview of the indicators included, their unit of measurement, and the dimension on which this variable will be measured should be provided, as well as what data should be collected [134]. Reflecting on the choices made for the final set of indicators is necessary to improve transparency.

3.3.2. Phase 2. Normalization of indicators

The different indicators have different units of measurement. These indicators must be normalized to aggregate in a CI. Therefore, the indicators will be expressed in homogeneous units of the identical range [10, 87, 133, 206]. This research considers the most commonly used normalization techniques: re-scaling (min-max), standardization (z-value), ranking, and distance to a reference point [134, 133, 10, 150]. The choice of a technique depends on the requirements of the CI and the appropriateness of a technique based on its advantages and limitations. Here a short description is given on these techniques.

- Rescaling: the normalized value is determined by converting the ranges from 0 to 1, irrespective of the original range of values. It is a simple and commonly used technique but shows some weaknesses in its sensitivity to outliers and extreme values and experiences difficulties scaling negative or zero values [134, 206, 180].
- Standardization (z-value): this normalization method standardizes the mean and standard deviation of the indicators to 0 and 1, respectively [203, 206]. It is a commonly used method to make the data dimensionless [150]. Still, it has its disadvantages in that standardization is sensitive to extreme values in the final CI and cannot be used in combination with multiplication aggregation [134, 180].
- Ranking: the values are scaled according to the assigned ranks from 1 to N, in which N represents the highest rank. This method is relatively simple to use. However, scores cannot be compared on value level because the ranking scale loses absolute-level information. Therefore, it is impossible to measure the value difference between scores [180].
- Distance to a reference point: the scales of indicators are converted to a reference point to calculate the normalized value. This is done by dividing the value by the reference value [180], which is an external benchmark [206]. Although the straightforwardness of this method, this method uses the outlier values of the data set for normalization. This means that when the outliers in this data set are very large, this may affect the reliability after using this method [134, 180].

The outcome of this phase should be selecting a normalization approach and adopting it on the indicators derived from the theoretical framework. Justification of the choices made for the normalization method and the procedure should be given.

3.3.3. Phase 3. Weighting of indicators

Each indicator is assigned a weight expressing relative importance [87, 134]. Weighting techniques can be objective or subjective. Objective weighting refers to constructing weights based on statistical or mathematical methods. Subjective weighting involves any expert judgment. The method of Equal Weights (EW) is also available. This weighting technique assigns the same weight to every indicator, indicating that they all have equal importance. EW can also be applied when there is not (sufficient) information available for reliable assignments of weights [87, 153]. The most used weighting techniques are listed below. See [134] for a more detailed explanation.

- Conjoint Analysis (CA): the weight is derived from how much value is attached to a certain indicator by a respondent and how much they would be 'willing to pay' for an option. The operation of this method and computation is relatively complex compared to other weight methods, as many respondents should be sampled, and the utility function should be specified [134].

- Principal Component Analysis (PCA): the (co)variation is analyzed to create weights and is commonly used when correlation exists. A relatively large data set, of which the definition may differ, but a common rule is to have more than 10 data points per variable, is needed. Therefore, this method is less applicable for small data sets as much data is needed. Also, PCA is sensitive to extreme values and changes in data, which are disadvantages of this method [134].

- Data Envelopment Analysis (DEA): weights are assigned based on the performance relative to an estimated benchmark found by linear programming. DEA can lead to difficulties in interpreting the weights of the individual indicators [134].

- Benefit of the Doubt (BOD): the CI is defined as the performance of a system relative to its benchmark performance. This method is commonly used in policy making, and weights express the priorities of policies. A downside of this technique is that categories are difficult to compare, and extreme values weigh heavier. Also, the effect of another normalization method may lead to considerable differences in the final values [134].

- Analytical Hierarchy Process (AHP): weights are constructed by pairwise comparisons where experts make trade-offs [160]. Despite being time-consuming, this subjective technique is often used for assigning weights, particularly for sustainability assessments [87], because it allows decision-makers to express their relative importance but has a built-in check for ensuring statistical consistency [203, 134].

The most suitable weighting technique for a CI should be determined based on its specific objective and requirements. As mentioned as one of the risks of developing a CI, assigning weights is subjective, which may affect the outcome and reliability of the CI and can therefore be a cause of disagreement [87, 206]. For this reason, additional attention should be paid to the choices made, and transparency should be provided in this process.

3.3.4. Phase 4. Aggregation of indicators

The weighted sub-indicators are aggregated and combined into the CI in this phase, which several techniques can do. The selection of aggregation method and related flaws can also lead to different results for the CI. Therefore, this decision should be well-reasoned to prevent criticism [87].

- Linear aggregation (LIN): the aggregated value of the CI is calculated by a summation of the sub-indicators and commonly used with complete compensability [133, 206]. Compensability refers to the allowance of trade-offs between the variables in a CI [128].

- Multiplicative aggregation (or Geometric mean (GME)): multiplication of the sub-indices results in the aggregated value for the CI. The indicators are partially substituted with each other and are preferred when full compensability is not desired [134].

- Non-compensatory multi-criteria analysis (NCA): NCA methods aggregate the sub-indicators based on designed criteria. This method is mostly used when it is not preferred to have any substitution between the indicators. NCA aggregates the indicators by achieving a 'compromise' between the objectives [134].

The aggregation method's selection should be reflected to complete this construction phase. Further, the potential correlation between indicators should be viewed, and whether the indicators may be substituted by each other [134].

3.3.5. Phase 5. Post-analysis evaluation of the CI

The final phase assesses the robustness of the CI. Several (subjective) judgments must be made while making the CI, and thus it is essential to evaluate upon choices, inputs, and structures of the CI [134]. [203] emphasizes that CIs should have more comprehensive and detailed evaluations to improve its robustness. The evaluation is done by executing an Uncertainty Analysis (UA) and examining the sensitivity to data or choices for methodologies with a Sensitivity Analysis (SA) [133, 208]. Often the evaluation of CIs is limited by solely performing an UA. By using both UA and SA for the evaluation of the CI, transparency on the construction process and underlying choices will be increased more than by just one analysis [134, 133]. The structure of the CI may be adopted and improved using the findings made during the evaluation [133]. For a complete evaluation of the CI, reliable conclusions should be drawn, together with identifying limitations and uncertainties [134].

The following elements are recognized as causes of uncertainty in CI building [134, 133]:

1. Indicator selection
2. Input data
3. Editing schemes for missing data
4. Normalization method
5. Weighting method
6. Aggregation method
7. Assigned values of the weights

The UA reflects on the potential sources that create uncertainty of the CI. It is investigated using the UA how these components impact the composition and outcome of the CI. This can be examined by varying the construction methods or using other data as input. CIs can be seen as models, and therefore statistical techniques can be selected to perform the analysis [133]. With the SA, the sensitivity of the CI is analyzed for changes in the sources of uncertainty [134]. While changing the input sources, an understanding of the impact of the indicators on one another should be gained. Because construction methods are also sources of uncertainty, the SA can shed more light on their significance [134, 132].

A measure should be constructed to analyze how different input values affect the final output of the CI. An answer should be formed to the following question: How- and to what extent is the final value of the CI affected by a source of uncertainty for building the CI? A statistical test can address this and provide that the CI is robust and does not extremely depend on the chosen methods [180, 79]. Variance-based approaches are appropriate analysis tools for conducting a SA [132, 203, 147]. Quantitative tests that can be executed to perform a SA are a correlation analysis, regression analysis, and partitioning of the output data [147]. Considering the objective of this SA, which is to determine how- and to what extent the final value is affected by uncertainty sources, a correlation analysis is suggested [97].

Commonly used correlation tests are the Pearson or Spearman correlation coefficient. The choice for one of these measures depends on whether the data is normally distributed and the relationship between the variables is linear [147]. Spearman's coefficient can be used when the variables are presented on an ordinal scale as it utilizes the ranks of each variable relative to another [147, 99].

3.4. How a construction method can be selected

The choice for a technique relates to the degree above subjectivity constructing a CI. This is why the decisions made in every phase need to be well-grounded, transparent, and answerable. Guidelines are proposed by [120] that help to decide which technique is most suitable and appropriate for each phase. These guidelines are visualized in Figure 3.2, which can be used as a structure to select techniques. The analyst makes the choices before constructing the CI.

The flowchart (Figure 3.2) identifies four different levels at which a decision must be made (i.e., blue squares). These correspond to the following factors: indicator type, aggregation type, comparison type, and weighting type. The choices made at the higher levels determine the availabilities of techniques at the lower levels, which are visualized in the yellow boxes. Different paths can be followed based on the decisions made at the tiers.

- **Type of indicators:** The choice corresponding to the type of indicator is to decide whether the components of a CI are substitutable. Substitutable (or compensability) refers to elements that a surplus of another part can offset [128]. When compensation is not allowed, indicators are of the latter (i.e., non-substitutable) category [120]. The nature of the indicator type affects the aggregation approach in the level below.

- **Type of aggregation:** Aggregation methods are simple or complex; a choice should be made depending on the target group and purpose of this CI. Simple aggregation methods are usually applied for a more general audience and vice versa [120].

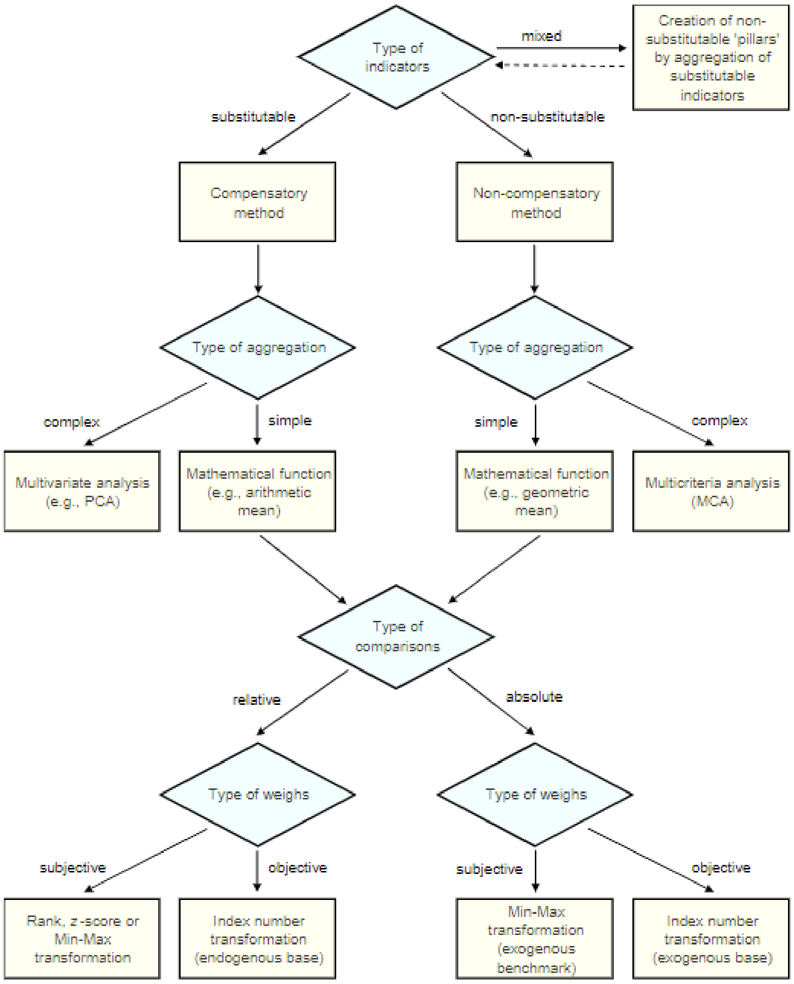

Figure 3.2: Flow chart to select the best methods for constructing Composite Indicators, from [120]

- **Type of comparisons:** Next, the objective of the CI determines if the dimensions are compared relative to one another or absolute.

- **Type of weights:** The method for assigning weights must be decided at the bottom of the flow chart, depending on the use purpose and objectives of the CI. Weighting can be objective or subjective, or equal weights can be assigned to the indicators.

3.5. Why benchmarking should be performed

The value of the CI is compared relative to the benchmark CI. Benchmarking is used for identifying performance gaps and is, therefore, a commonly used method in addition to performance measurement [204]. The added value of sustainability benchmarking is most significant when the benchmark reflects the best practices [49], commonly a target performance. Therefore, competitive landscaping benchmarking, where the performance of different competitors is measured and compared, is less suitable for this research. The use of target performances for the benchmarks is more appropriate in this research context. Benchmarking also allows for easy comparison between the actual- and desired performance [49].

Target performance can be done by comparing a company's actual and target performance. This can be done in two ways; the relative performance of a company in which the actual performance is compared with a benchmark, and the magnitude of the performance gap. The performance gap between the actual company performance and the target performance should be minimized for best performance [49].

First, a company's relative performance RP is calculated (see Equation 3.1). Here, CI_a is a company's actual performance, and CI_b is the target performance [49].

$$RP = \frac{CI_a}{CI_b} * 100\% \tag{3.1}$$

The actual and benchmark performance differences can identify the performance gap M. If the best practice is the maximization of the indicator values, Equation 3.2 should be adopted. If the best performance is achieved when the importance of the indicators is minimized, the performance gap should be calculated with Equation 3.3 [49].

$$M = CI_a - CI_b \tag{3.2}$$

$$M = CI_b - CI_a \tag{3.3}$$

3.6. Main findings chapter 3

This chapter has created insight into how company performance can be measured when environmental and economic dimensions are included by outlining the construction steps of a CI, proposing guidelines on how techniques can be chosen, and how performance can be benchmarked.

Thereby, knowledge is created to answer the sub-research question 4a) *How can companies use a CI to assess their performance on multiple dimensions?*

Companies can use a CI to measure, analyze, and evaluate product returns on their performance while considering both environmental and economic impact. CI are tools to measure performance, which supports companies in measuring and tracking progress and identifying potential areas for improvement in processes [116, 125, 92]. CIs allow for easy comparisons, summarize large sets of information of individual indicators, and facilitate communication on a topic or problem [138, 207, 203, 206]. In the context of this research, CIs can provide an understanding to companies of their current performance, how the performance of return methods differ, how implementing actions affects their performance, monitor their progress, and communicate these findings with customers to increase transparency or with governments for reporting of their performances.

The added value of this CI will increase if the output from the CI can be compared relative to a benchmark, so companies know how far they are in reaching certain goals [204]. The results can be compared with a performance gap to compare the actual performance with this benchmark performance. Companies should minimize this gap to achieve the highest performance [49], which can be measured and tracked using the CI.

Next, the sub-question *4b. Which steps must be performed to construct a CI for an assessment on multiple dimensions?* can be answered.

The structure of a CI typically involves five steps: selection/identification, normalization, weighting, aggregation of the variables, and evaluation [133]. During these phases, choices are made regarding the techniques and methods used, which can be a source of disagreement because of any subjectivity that may arise. Each step increases the probability of subjectivity and bias. To lower this engaged risk of subjectivity, all choices made for constructing a CI should be transparent and well-substantiated. Additionally, special care must be given to inspect the robustness and reliability of the CI, which can be done by performing an UA and SA [203].

4

Conceptual design of the Composite Indicator

In this chapter, the conceptual model for the Composite Indicator (CI) is developed and provides a clear roadmap for its actual construction, including the methods to use and the data to collect. This chapter will form an answer to sub-question 4c) *What methods should be selected to construct the CI for product returns assessing environmental and economic performance?*. First, the objective and scope of the CI are defined. The methods used for the CI are selected, motivated, and discussed in section 4.2. The selected methods are explained in more detail in section 4.3. Lastly, guidelines and requirements for the data collection are presented in section 4.4.

4.1. Objective and scope of the CI

The intent of the CI is to provide fashion companies with an understanding of product returns, focusing on assessing its impact on their environmental and economic performance and considering the return methods. With the knowledge gained from this assessment, companies can compare and analyze different variants of return methods on their performance. Moreover, insights are created into potential areas of environmental improvement while ensuring that their efforts are also economically feasible. This can support companies in making more environmentally sustainable choices to improve the impact of (sub-activities) on their product returns. In addition, the CI should be transparent and improve transparency on the impact of the returns and return methods as well, to be used sector-wide and communicate the insights with customers or other involved actors like governments or shareholders. Companies can encourage and inform their customers about the environmental consequences of their return behavior. This can eventually help make more environmentally conscious decisions on the customer side [194, 22].

Although the primary focus of this CI is to improve the environmental impact of returns in the fashion industry, the economic dimension is also considered in this CI. This decision is made because the fashion industry is primarily profit-driven. Therefore it is worth considering the costs of return methods assessing a company's economic viability. If a return alternative would perform best based on Greenhouse Gas (GHG) emissions but is highest in costs for a company, a trade-off is crucial to remain economically feasible. The objective of the economic dimension is to provide insight into the economic performance of the considered indicators. With this, companies are assisted in making a well-balanced trade-off between the performances of the dimensions and each other. Including these environmental and economic dimensions for the performance measurement increases reality [203, 205].

A specific CI for product returns should be developed to assess environmental and economic performance to reach these objectives. All activities that impact the returns process are relevant and should be included in the CI, which needs to be constructed in a transparent way. For interpretation purposes, it is crucial that the CI is straightforward to understand and use and that companies can easily compare the different alternatives and make trade-offs.

4.2. Selection of sub-methods

This section elaborates on the choices for the methods to perform the steps for constructing a CI. A structured approach is used as outlined in section 3.4. The selection is based on the objective, scope, literature reviews, and expert consultation.

First, it is determined whether the sub-indicators of the CI can compensate for each other. According to [128], *compensability* can be defined as the existence of trade-offs between variables in the CI. This means that a high value of some variables may compensate for the lower values of other variables. Also, compensability refers to the level of correlation and dependency between the variables. Compensability can either be complete or partial. Reviewing the objectives of the CI and the theoretical framework, a partial compensatory approach is found to be most appropriate rather than complete compensability. The partial compensatory approach allows for trade-offs between indicators made by multiple decision-makers. Also, there is, to some extent, compensation for lower and higher scores of indicators instead of complete compensation [128, 129]. An example is given to illustrate the suitability of this choice for the context of this research: in a scenario that shows low costs but a considerable amount of emissions, the final CI value is likely to be not very high as the performance should depend on a combination of both. The low cost is preferred for a company and may compensate somewhat for the large emissions, but complete compensability is certainly not desired [203], as companies need to improve their environmental impact. In addition to this, the theoretical framework of Table 4.1 shows no complete independency between the variables [120]. Considering these conditions, a partial compensatory approach is most appropriate for this CI.

The CI should be functional for fashion companies, and the results should be easily interpreted and communicated with stakeholders and companies. Therefore, a more straightforward (e.g., mathematical function) aggregation method is chosen instead of a more complex method as the latter is less suitable for a general audience [120]. Straightforward methods are Linear aggregation (LIN) and Geometric mean (GME). LIN are less sensitive to outliers in the data and are commonly used for aggregation. LIN suggest complete compensability and mutual independency [133]. Although LIN can still be used, the aggregation of individual weights by a multiplicative function (GME) is better suitable for the construction of this CI [87]. The multiplicative aggregation approach makes the differences in the performances of the considered dimensions (in this research, environmental and economic) explicit [180]. As an outcome of this, this method assists in identifying the indicators that are performing less and promotes improved company performance here. Also, it controls for the effect of specific indicators on the final value of the CI [19].

Further, consideration is given to how the weights should be assigned. The variables in this CI are relatively compared amongst each other rather than absolute. This is because this CI aims for a fashion company to make a trade-off between environmental and economic performance. The company should compare the indicators of the environmental dimension relative to the economic dimension. For this reason, a relative comparison approach is chosen.

The relative weighting technique can be subjective or objective. The subjective weighting of indicators is preferred for this CI. Different fashion companies should be able to use the CI and make company-specific trade-offs. Companies have different opinions, preferences, and targets. Subjective weighting allows companies to assign weights based on their values and preferences [180]. So, a subjective, relative weighting method for the indicators is desired in this CI. The Analytical Hierarchy Process (AHP) is an appropriate method that satisfies both conditions and is often used when sustainability indicators are included in the CI [87]. A fundamental property of AHP is that expert knowledge and experience are at least as important as the data for making decisions [190]. This technique allows for subjectivity, and the weight expresses the trade-off between the indicators. Also, this subjective weighting technique has a built-in consistency standard and scores high for transparency [134]. However, AHP is a time-consuming weighting method, as careful consideration must be given to selecting experts, computing weights, and verifying the consistency of the weights [133, 87]. An alternative method that satisfies the weighting conditions of this research is the Data Envelopment Analysis (DEA). However, this method is considered less suitable for this research as it may construct less realistic weights, affecting the robustness of the CI [161]. Therefore, AHP, a relative comparison approach with subjective weighting, is selected.

Lastly, the normalization method needs to be chosen. As AHP is selected, [120] suggests using either a ranking, standardization, or re-scaling transformation method for the normalization. The ranking is not an appropriate method when the objective of a CI is to reflect on the differences in the performances of the indicators [180], making this method unsuitable for fulfilling the objectives of this CI designed in this research. The re-scaling and z-score standardization methods can be used as they can measure the relative differences between the variables [180]. The indicators show no variances in indicator bearing, implying they can all be interpreted similarly. For this research, lower values imply better performance. The re-scaling method is simple and can widen the ranges of small variable intervals; but is less capable of maintaining proportionally [134]. Z-score standardization can better handle outliers in the data but is not usable for a geometric aggregation method as this normalization method leads to negative values. Because GME is selected for aggregation, normalization will be done by re-scaling and not by z-score.

In summary, a visualization of the chosen methods for every phase can be found in Figure 4.1. The following subsections will provide further information on the techniques.

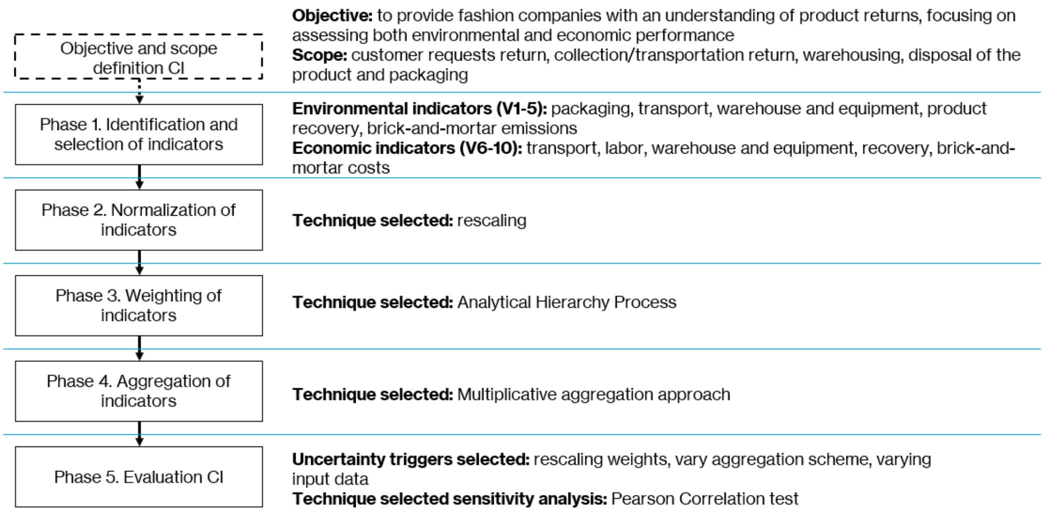

Figure 4.1: Conceptual design CI measuring the impact of product returns on companies' environmental and economic performance, source: (Author)

4.3. How the CI for product returns is designed

This section will provide detailed information on the chosen methods for constructing the CI. The following five phases will be covered subsequently: selection of variables, normalization of variables, the weighting of variables, aggregation of variables, and as the final stage, the evaluation.

4.3.1. Phase 1. Selection of the indicators

First, a conceptual framework that includes all relevant variables is created, which serves as a foundation for selecting variables. A comprehensive literature review on the product returns process is performed in chapter 2 to identify what is desirable to measure. Complementary to the literature, expert consultation is done for external verification. The relevant indicators for both dimensions are briefly described and discussed below.

Environmental set of indicators

The literature study has divided the returns process into several phases to assess the environmental impact. These are the preparation phase, collection phase, product handling and processing, and recovery and disposition phase. Different logistic activities identified from literature affect the magnitude of the environmental impact, as presented in section 2.6. For the final selection of the variables for the theoretical framework, this set of factors is narrowed down to a more comprehensive selection in which double counting is avoided. The environmental variables included in this CI are V_1 packaging emissions, V_2 transport emissions, V_3 warehouse and equipment emissions, and V_4 product recovery and disposal emissions and V_5 brick-and-mortar emissions.

Clarification choices environmental indicators

Several choices for including indicators in the theoretical framework require additional clarification. First, the return preparation phase has identified packaging and labeling emissions as impact sources. The share of labeling emissions is considered to be relatively little relative to the packaging emissions and will not likely be of significant impact on this. Therefore, labeling emissions will not be included in the final theoretical framework. Packaging is an important contributor to additional waste for a company, according to a manager of a fashion warehouse. Double counting of packaging emissions is avoided by using an Emisison factor (EF) that considers the whole life cycle of the packaging material for a particular waste treatment method [84]. The environmental impact of transport can be calculated using indirect transportation emissions and direct energy consumption. The values of these variables depend on the factors identified as crucial for the environmental assessment of the transportation phase like the type of modality or distance traveled. Vehicle energy consumption can be used as input for calculating transport emissions. However, including energy consumption and transport emissions in the environmental assessment increases the risk of double counting GHG emissions [84, 83]. This should be avoided. Considering the context of this research, the most appropriate variable to include is transport emissions rather than vehicle energy consumption to understand the companies' environmental impact in terms of GHG emissions. So, the GHG emissions from transporting a product over a certain distance are included in the framework.

There is also an overlap in the emissions and energy consumed by the equipment and vehicles used for handling and processing returns at the warehouse. Therefore, the same logic for avoiding double-counting is applied as described above. Emissions created by all warehousing equipment needed (i.e., conveyor belts, forklifts, stacking cranes) and emissions that arise in warehousing operations, including heating, cooling, and other sources of GHG pollutants, are included as one indicator in the final framework.

Economic set of indicators

A breakdown of the high cost of product returns for a company is given in section 2.5. A reduced set of variables is included in the theoretical framework. These are V_6 transport costs, V_7 labor costs, V_8 warehouse and equipment costs, V_9 recovery costs, and V_{10} brick-and-mortar store costs.

Clarification choices economic indicators

Expert consultation from Metyis and other fashion industry experts has confirmed the relevant costs for returns for a fashion retailer. The transport component also captures the logistics for arranging transport from the customer to the warehouse, including fixed, variable, staff, mode characteristics, and general operating cost elements. Labor costs refer to the direct and indirect costs for human resources and labor needed to handle returns, including hourly wages, benefits, and insurance. Utilization and rental of warehouse space and equipment for product returns are combined into one metric. This is because these costs are generally connected with companies' financial statements and are most of the time leased on an annual basis. Further, disposal and recovery costs of the packages and products are combined into one metric. According to an industry expert, these actions often take place together. Product recovery costs consist of either restocking, landfill, or incineration. For packaging recovery, recycling, landfill, or incineration alternatives are included. The utilization and processing costs for return operations in a brick-and-mortar store are integrated into one variable.

Theoretical framework

The theoretical framework for this research is shown in Table 4.1. This framework provides an overview of the dimensions, the variables representing each indicator, and units of measurement. The column on the right shows the direction of the variability of a variable on the company's performance. This attribute of an indicator is called indicator bearing [150]. A positive direction means that if a variable's value increases, the company's performance improves and vice versa. On the other hand, a negative direction indicates that a lower value of that respective variable is preferred to obtain higher performance [207], so for example, a high value of transport emissions represents worse environmental performance, indicating a negative variability [19].

4.3.2. Phase 2. Normalization of the indicators

The normalization of variables will be done by re-scaling. Rescaling normalizes values based on the variable's range (minimum and maximum value) and widens the interval of all variables [134, 206, 180]. The normalized indicator values can be calculated using Equation 4.1 [203]. Here, $min_i(x_{ij})$ and $max_i(x_{ij})$ are the minimum and maximum values for indicator j considering all return methods or return policies i [180]. The aggregation of the indicators is done by multiplication, so values with a 0 will lead to an infeasible solution. Therefore, the formulation of the rescaling equation is adapted to Equation 4.1 from [203].

$$I_{ij} = 1 + \frac{max_i(x_{ij}) - x_{ij}}{max_i(x_{ij}) - min_i(x_{ij})} \tag{4.1}$$

Table 4.1: Theoretical framework including the indicators and units of measurement, source: (Author)

Dimension		Description	Unit of measurement	Direction of variability
Environmental	V_1	Packaging emissions	[$kgCO2e$/ *returned product*]	Negative
	V_2	Transport emissions	[$kgCO2e$/ *returned product*]	Negative
	V_3	Warehouse and equipment emissions	[($kgCO2e$/ *returned product*]	Negative
	V_4	Product recovery emissions	[($kgCO2e$/ *returned product*]	Negative
	V_5	Brick-and-mortar emissions	[$kgCO2e$/ *returned product*]	Negative
Economic	V_6	Transport costs	[$euro$/ *returned product*]	Negative
	V_7	Labor costs	[$euro$/ *returned product*]	Negative
	V_8	Warehouse and equipment costs	[$euro$/ *returned product*]	Negative
	V_9	Recovery costs	[$euro$/ *returned product*]	Negative
	V_{10}	Brick-and-mortar costs	[$euro$/ *returned product*]	Negative

Where:

i	The return method i, $i = \{1,...,n\}$
j	The value of indicator j, $j = \{1,...,m\}$
x_{ij}	The raw value of indicator j for return method i
I_{ij}	The normalized value of x_{ij}

4.3.3. Phase 3. Weighting of the indicators

The variables are relatively weighted according to the technique AHP, allowing for some subjectivity. The variables are compared per pair. First, the decision maker decides which variable in the considered pair is more important. Second, the decision maker expresses how much more important this variable is by assigning a score on a ratio scale [161, 159, 133]. The final values of the weights express trade-offs and are not measurements of the importance of indicators relative to another [134].

Each pair of two variables is compared based on a relative preference considering a given objective. The relative preferences of the decision-makers are defined on a semantic scale that ranges from 1 to 9 [134, 159, 144]. This scale is widely validated in literature and practical applications [159]. A value of 1 (weak preference) is given when both indicators are equally important, a five corresponds to a strong preference, and a 9 expresses an extreme preference. So, a nine should be interpreted as an indicator nine times as important relative to the other [142]. These preference relationships are further elaborated in Appendix B.

A n x n matrix, denoted by A, is constructed in Equation 4.2. Each element a_{ij} expresses the relative preference assigned by the decision maker for alternative i to j, where the alternatives represent the variables [142, 159]. As there are 10 variables identified for the CI in this research, the size of the matrix is 10 x 10. Several conditions should be met in this matrix. The pairwise comparison between the same variables should equal one, as expressed in Equation 4.3. Also, the reciprocal property should be satisfied (Equation 4.4) [190]. This results in a reciprocal matrix as presented in Equation 4.2, where $a_{ij} = w_i / w_j$ [142, 100].

$$A = [a_{ij}] = \begin{bmatrix} 1 & a_{ij} & \dots & a_{1n} \\ 1/a_{ij} & 1 & \dots & a_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ 1/a_{1n} & 1/a_{2n} & \dots & 1 \end{bmatrix} \tag{4.2}$$

Where:

$$a_{ii} = 1 \tag{4.3}$$

$$a_{ji} = 1/a_{ij} \tag{4.4}$$

After the expressions of the judgments in the matrix, the relative weights will be calculated by the principal right eigenvector approach of matrix A [159, 142]. This approach calculates a priority vector that represents the position of each variable relative to the others [142]. First, all elements in a column of matrix A are summed. Next, the columns are normalized by dividing the comparison scores of each cell in the reciprocal matrix by the sum of its column in (Equation 4.5), where ew_{ij} is the element weight. Third, the weights w_{ij} are obtained by taking the average of each row (Equation 4.6) [100].

$$\mathrm{ew}_{ij} = \frac{a_{ij}}{\sum_{i=1}^{n} a_{ij}} \tag{4.5}$$

$$w_{ij} = \frac{\sum_{j=1}^{n} \mathrm{ew}_{ij}}{n} \tag{4.6}$$

Consistency check

The comparison scores are based on the judgments of decision-makers. Therefore, as part of the AHP, it is important to perform a consistency check on the reasonability of the scores and the new priority vector values. The Consistency Ratio (CR) is a statistical test, which can be calculated with equation4.7. In this formulation, n represents the size of the matrix, λ_{max} the largest eigenvalue of the n x n pairwise comparison matrix, and RI is the average random consistency index [134]. In Table 4.2 the critical RI values for the number of variables in matrix A can be found.

The calculated value of the CR indicates the level of consistency, of which the acceptable level depends on the size of the matrix. A significantly low value indicates an acceptable estimate of the relative weights [159]. There are specific baselines, which are when n=3, the CR should be 0.05, 0.08 with n=4, and 0.10 with n>=5 [167, 142]. A lower or equal value than this reference represents acceptable consistency in the comparative judgments. If this value exceeds the references, the judgments should be reviewed to reach an acceptable level of consistency [167].

$$CR = \frac{\lambda_{max} - n}{(n-1) * RI} \tag{4.7}$$

Table 4.2: RI values corresponding to the number of variables n, from [142]

n	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
RI	0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49	1.51	1.48	1.56	1.57	1.59

4.3.4. Phase 4. Aggregation of the indicators

The multiplicative aggregation approach, also called weighted geometric aggregation (GME), provides an in-between solution between the full and non-compensability of the different variables. By multiplying the weights and normalized indicators, a value of the CI is obtained that reflects the relative importance of each indicator and how much an individual indicator contributes to the total score of the CI [207, 203].

The previously calculated functions are used as input for the formula for aggregation (Equation 4.8). In this equation, w_j expresses the weight of indicator j for product return method i. I_{ij} is the normalized value of indicator j for return method i. CI_i expresses the value of the CI for return method i [203].

$$CI_i = \prod_{j=1}^{10} I_{ij}^{w_j} \tag{4.8}$$

4.3.5. Phase 5. Post-analysis evaluation of the CI

The choices made in each phase in constructing the CI can all be subject to criticism. In theory, using different methods to build the CI is possible, which may lead to different results [207]. To improve the robustness of the CI, it is essential to provide transparency on the construction process in the first place, and a Uncertainty Analysis (UA) and Sensitivity Analysis (SA) are performed secondly [134].

Uncertainty analysis

For the UA, different input sources embedded with uncertainty are studied. These sources are referred to as uncertainty triggers [134]. The chosen method for the UA is sustained, followed by a description for performing that method. This research inspects three uncertainty triggers in more detail, the weights, aggregation method, and the input data. It is worth mentioning that it would add value to analyze the uncertainty of the normalization method. However, in the context of this CI, the rescaling method is the only appropriate normalization method considering the alternative methods. The z-standardization can measure differences between the values but cannot be used in combination with the multiplicative aggregation approach. Other normalization methods, like ranking or distance to a reference point, do not take the absolute differences between the values into account and are therefore unable to measure or analyze the difference in performance [133]. This is a requirement for this CI; therefore, the uncertainty of the normalization method is not analyzed further in this research.

Uncertainty trigger X_1. Weighting method

A source of uncertainty for this CI is the assignment of weights in the AHP, particularly because subjective weighting is used. The first trigger for this uncertainty analysis is, therefore, weighing. A different weighting scheme can gain a further understanding of the robustness of this CI. The AHP already performs a consistency check reflecting on the realism of the assigned weights. For this reason, rescaling weights is sufficient to examine the robustness and is referred to as the first trigger in this UA [133]. Rescaling the weights will be done by questioning a different group of experts who must assess the weights according to a defined perspective. The same criteria apply to the number of experts and the consistency ratio.

Uncertainty trigger X_2. Aggregation method

The second trigger X_2 of uncertainty is the aggregation scheme. The nature of this CI requires that the aggregation scheme satisfy the partial compensability of the indicators of this CI. Therefore, the non-compensatory weighting method is not suitable. Additionally, using a multi-criteria aggregation is incompatible when using AHP [133]. Considering these technical feasibilities, the arithmetic mean can be used, where the normalized values are summed to an arithmetic mean. This aggregation method can be more extreme than the geometric mean as it substitutes values to a larger extent with each other [180]. The following equation can be used to determine the values according to linear additive aggregation, Equation 4.9 and Equation 4.10 [133].

$$CI_i = \sum_{j=1}^{10} I_{ij} w_j \tag{4.9}$$

$$\sum_j w_j = 1 \tag{4.10}$$

Uncertainty trigger X_3. Input data

Assumptions are likely to be made when not all input data is provided, so the uncertainty of this source will be inspected [134]. This will be done by making explicit assumptions and performing a SA.

Sensitivity analysis

The correlation of the uncertainty triggers on the final value of the CI are inspected with a statistical test [203, 147]. The variables are not expressed in ranks, so the Spearman correlation is unsuitable, and Pearson is used [99]. This test is two-tailed, as the variables can change in two directions (positive or negative) [147, 99].

A trigger's impact is isolated to analyze the correlation with Equation 4.11. In this formulation, n is the number of variables, and x and y are the variable sets $(x_1, y_1), (x_2, y_2), \ldots, (x_n, y_n)$ [99].

The coefficient r ranges from -1 to 1. A negative correlation is indicated by -1, 0 is no, and 1 expresses a perfect positive correlation [20]. For each trigger, a set of hypotheses are formulated. The null hypothesis (H_0) states no significant relation between the examined variables, and the alternative hypothesis (H_1) states a significant relationship at a certain confidence level [147, 99, 203]. The p-value determines the significance of this relationship. H_0 is accepted if the significance level is below the p-value, and H_0 is rejected otherwise, meaning there is a significant relationship between the variables [20, 203, 99]. The p-value is calculated using the t-distribution, presented in Equation 4.12 [99].

$$r = \frac{n\sum xy - (\sum x)(\sum y)}{\sqrt{(n\sum x^2 - (\sum x)^2) - (n\sum y^2 - (\sum y)^2)}} \tag{4.11}$$

$$t = r * \sqrt{\frac{n-2}{1-r^2}} \tag{4.12}$$

4.4. Data collection

This section provides insight into the data collection requirements. The CI will investigate several return scenarios, which can be return methods or return policies. For each method, a value x_{ij} is calculated, expressing the raw indicator value j for product return method i. In total, there are 10 variables identified from Table 4.1 and including their unit of measurement. These are: V_1: packaging emissions, V_2: transport emissions, V_3: warehouse and equipment emissions, V_4: product recovery emissions, V_5: brick-and-mortar emissions, V_6: transport costs, V_7: warehouse and equipment costs, V_8: labor costs, V_9: recovery costs, V_{10}: brick-and-mortar costs.

Required data and guidance on the data collection

This subsection guides which data needs to be collected to measure the variables, what sources to use, and how to analyze the data.

V1. Packaging emissions

The required data to determine the packaging emissions are the type of packaging material and the weight of the packaging material, which should be collected through external client data. A material-specific EF can be retrieved from the literature, CO2emissiefactoren, DEFRA emission sources, and EPA. This EF is multiplied by the mass of a package according to the approach suggested by [84]. Further, data on the waste treatment strategy should be collected to select the correct EF for the waste treatment. If the client cannot supply this data, assumptions are made about the most frequently used materials for packaging and corresponding waste treatments.

V2. Transport emissions

The transport emissions can be calculated by the fuel- or distance-based method. The appropriateness of the methodology for transport emissions depends on the analysis objectives and the availability of data [84]. The fuel method requires detailed data on the volume and fuel types used [84]. This level of accuracy in data may not be feasible for the time scope of this study. The distance-based approach requires less detail in data [84]. The following data needs to be gathered to calculate the transport emissions with this method: the transport modes used, the distance traveled per returned product, the return method, the transported weight or volume of the product, and the vehicle capacity. Different data sources can be used and combined to retrieve the necessary information. The client should provide data on the input sources. This provider should also be contacted if the transport process is outsourced to a Third Party Logistics Provider (3PL). Knowledge of the type of modality is needed to select the correct EF, which can be retrieved from external sources like CO2emissiefactoren, DEFRA, EPA, or TNO. Different transportation networks for each return method should be considered to calculate the emissions to obtain accurate values. The emissions are determined according to in-store returns, home pick-up, and collection points network structures. A more detailed description of the data and additional assumptions is provided below.

Return method - Brick-and-mortar returns

The transport emissions are calculated using the distance method as collecting fuel data of customers' shopping trips is complex and not assumed to be feasible within the time scope of this research. The input data necessary are the modality, the mass of a product, the customer's location, and the store's location. If the product is transported from the store to the warehouse, additional data should be collected on the vehicle route, vehicle type, warehouse location, and total journey distance traveled. The client should provide the location of the customer and the physical stores. This is used as input to determine the distances traveled in kilometers. If it is impossible to collect this input data, assumptions for the average distance driven for a shopping trip in the Netherlands are made based on data from Centraal Bureau voor de Statistiek (CBS) [118, 27].

The level of accessibility affects the choice of the modality of citizens [27]. Slow modes of transportation (bike, walking, bus, metro, tram) are preferred in the Netherlands under the threshold of 6 kilometers [27] if distances longer than 6 km need to be traveled, cars are mainly used for shopping trips [27, 28]. The top three most used cars per fuel type are petrol, diesel, and electric vehicles in the Netherlands [29]. Suppose it is impossible to retrieve any data on the modality used for this transport by customers. In that case, it is assumed that when a customer needs to travel less than 6 kilometers to the physical store, an average EF of the slow transportation modes is utilized. When the customer needs to travel distances larger than 6 kilometers, an average EF for the car will provide a reasonable approximation [84].

Return method - Home pick-up

To determine the transportation emissions per product return, the following data must be collected with the client and supplemented by 3PLs: the number of return requests served in one journey, the vehicle characteristics and type, the location of the return requests, and the location of the final destination. Suppose it is not possible to retrieve this complete set of data; in that case, assumptions should be made on the number of stops per journey based on the vehicle's maximum payload and the package's dimensional mass. This can be done by using an average EF for the transport vehicle [84], and the average distance per pick-up round (50 km) can be used for the distance calculation [118]. In the worst-case scenario, the emissions can be calculated using the total transport costs and the modality used [84].

Return method - Collection point

Three transport activities need to be calculated. The transport emissions for the first activity can be determined similarly to the in-store transport emissions, where the distance is determined from the customers' location to the collection point, using data from the retailer and 3PL their collection points. The latter is available on the websites of the 3PL. The second transport activity to consider is vehicle journey emissions. The input data necessary for determining the transportation emissions per product by a collection point are the number of collection points served in a single route, the location of the collection points and the final destination, the vehicle characteristics, and the number of parcels picked up per collection point. The client should supply this, preferably in cooperation with their 3PL. If this data cannot be collected, assumptions should be made for this measure. The number of parcels picked up is limited by the vehicle's maximum payload capacity and time constraints. Based on the dimensions of a product package, an estimation of the number of packages transported by one vehicle can be made. The average distance driven on a collection round can be used for the distance calculation if needed [51], and an average EF for the transport vehicle can be used if data lacks [84]. This can be found in the literature. In the worst-case scenario, the emissions can be calculated using the total transport costs and the modality used [84].

V3. Warehouse and equipment emissions

Energy consumption data is expressed over a certain period and should be available to the client. Once data is gathered from the warehouse's energy consumption, the warehouse emissions can be determined. A proportion of the total warehouse emissions will be allocated to product returns depending on the area. The warehouse emissions given to returns should be divided by the number of returns handled at the warehouse over the same period considered to determine the warehouse emissions per product return. The client should provide the following data: fuel and electricity consumption, warehouse space, and return handling area. Supplementary data can be found through literature studies; for example, [42] studied returns in warehouses, [75, 154] made an environmental assessment of general warehouse emissions, and [118] has taken warehouse activities into account in their carbon assessment. The EFs for this calculation are most accurate when location-specific; sources are CO2emissionfactors, DEFRA, and EPA. In the worst-case scenario, the emissions can be approximated using the total space used for product return handling at the warehouse, the cost structure (leased or owned), and the warehouse location [84].

Data should be collected on the number of warehousing equipment, the type of equipment, the operating hours per day, and the power consumption of the equipment. According to an expert with industry knowledge, the client, their warehouse manager, should have insights into these numbers. It could be that this data cannot be provided entirely by the client source for this research. In that case, additional assumptions should be made based on the type and number of equipment used for handling/processing returns at warehouses and the energy consumed by equipment in a warehouse. Studies of [75, 153] have assessed the emissions of warehouse equipment in the US. If the total equipment emissions are known, a fraction of the whole equipment emissions must be allocated to product returns. This will be the final value for this indicator.

V4. Product recovery emissions

The emissions created during the product disposition depend on the mass of the product and the chosen waste treatment. The client should collect data on the number of products handled by a treatment method, the type of treatment method, and the mass of the product. Client data will be the most accurate and reliable source of data. If no data is given on the recovery method chosen, insights are gathered through interviews with experts in the industry. The waste treatment EFs can be derived from DEFRA, CO2emissionfactoren, or EPA.

V5. Brick-and-mortar store emissions

To measure brick-and-mortar store emissions, data should be collected on the consumed energy at the store and the time a product return spends there. The client should provide this data, as they receive invoices for their energy consumption and electricity used at the store and have insight into their product stock levels. If this data cannot be provided, assumptions can be made regarding the store's size, location, number of products handled, and energy consumed. In the worst case, information on the store area and the number of returns dealt with there [84] should be collected, which can be retrieved from the literature or publicly available reports.

V6. Transport costs

The data that should be collected to calculate the transport costs are the distance driven; the modality used, the vehicle load, and the mass of the transported package. Sources to contain this data are the external client and possibly the 3PL to have the desired level of accuracy in the transport costs. Literature or reports can be used as a secondary source if this data is insufficient; for example, [187] provides detailed insight into key economic figures of freight transport. Once the total transport cost for a vehicle route is known, this amount should be converted to the cost per product by dividing the total costs by the number of products transported. When this data cannot be retrieved, assumptions should be made based on the shipment sizes. Therefore, a vehicle's maximum payload capacity and the product package's length should be known or determined [45].

V7. Labor costs

Necessary data is the number of employees, the time spent per employee on inspection, restocking, band receiving of product returns, the total labor costs of employees at the warehouse, and the external overhead expenses. The client should provide this data. By dividing the total labor costs for returns by the number of product returns dealt with during the period, the labor cost per product return can be determined [45, 50]. Suppose this data cannot (entirely) be provided. In that case, additional assumptions should be made based on the workforce required for handling/processing returns at warehouses and the total labor costs of warehouse employees. This data can be found in studies of [89] and [42]. Data on total costs can be found in companies' financial statements, and based on literature, assumptions can be made about the workforce needed.

V8. Warehouse and equipment costs

Cost on the handling and processing of return logistics at a warehouse provided by an external client. These costs include rent, mortgage payments, utilities, insurance, and security. A proportion of these costs should be allocated to return handling. This proportion is based on the time a product returns spent at the warehouse or the number of products over a time period. It is preferred to get this data from the client. Additional assumptions should be made if this data is not entirely provided on the area dedicated to handling/processing returns at warehouses and the cost of operating, which need to be verified using expert consultation.

V9. Recovery costs

Recovery costs consist of the recovery cost of a product and its packaging. The number of products per recovery or disposal method should be provided to derive a product's recovery cost. Country-specific disposition fees for landfill or incineration can be derived from European statements when client inputs on this lack [69]. This data can be supplemented by an expert consult specializing in clothing disposition. If this data is insufficient, secondary literature sources can be used. The cost for storage of a product is derived from the total storage costs at the warehouse and the number of product returns stored, preferably provided by the client. Otherwise, this can be approximated using findings of the study of [89] and expert knowledge. The packaging disposal and incineration fees can also be derived from the municipal waste charges if client input is not provided [39]. This can be supplemented with packaging-material-specific recycling fees from literature [73].

V10. Brick-and-mortar costs

The data that should be collected are the following: rent, mortgage payments, labor, insurance, and security costs. To specify the return costs, information should be provided on the estimated time and space for return handling tasks at the store and the number of products handled in the store over a time period. The primary source of data is client data. Otherwise, assumptions should be made based on the labor needed area dedicated to returns at a store to handle product returns based on the literature or reports.

4.5. Main findings chapter 4

This chapter aimed to answer SQ4c) *What methods should be selected to construct the CI for product returns assessing environmental and economic performance?*

The following methods should be selected considering the requirements and findings of the previous chapters: normalization by rescaling, AHP weighting, and multiplication aggregation, which is visualized in Figure 4.1. The data collection requirements and guidelines are identified for every indicator based on internal and external sources. Additional attention is paid to the availability of data sources, as this affects the requirements and measurement method. Several alternatives are defined for each indicator, and experts check whether a company can obtain the input data requirements.

5 Measurement with the Composite Indicator

This chapter will design the Composite Indicator (CI) to measure a company's environmental and economic performance for product returns. First, an introduction is given to the fashion retailer of the base case in section 5.1, followed by a description of the data set used. Second, the data collected for each indicator and additional assumptions will be described in section 5.2. Third, the model is designed in section 5.3, where the performance of the base case is measured. Lastly, the insights found with performance measurement are analyzed and evaluated in section 5.4. Question 4d) 'How can the current state of a company's performance be measured using the CI?' is answered.

5.1. Description of the base case

Data from a fashion retailer is collected to test the CI and to analyze and compare the performance of the return methods. The retailer is an international fashion company active in online and offline retailing channels. The fashion company is part of a larger global fashion group. The company offers all types of fashion clothing, such as shirts, dresses, tops, trousers, skirts, blouses, and jeans. The company is mainly active in the downstream supply chain, which entails the production of clothes by manufacturers to the point of customer consumption. The management and operations for handling returns are also part of the downstream supply chain activities. The company offers free returns to customers within 30 days of receiving the item, and depending on the channel the item was purchased, a return method can be selected.

The customer data is limited to the geographical scope of the Netherlands. This means that only customers returning items from the Netherlands are included. The data shows all products purchased and returned at the retailer's e-commerce channel and brick-and-mortar store for the time period of one year (Jan.-Dec.). The retailer operates one brick-and-mortar store in the Netherlands where customers can hand in returns. Other return alternatives offered are through home pick-up and at collection points.

The products collected at the brick-and-mortar store are either resold in-store or returned to the warehouse. Returns handed in through collection points or home pick-up can be transported to the warehouse or relocated to the brick-and-mortar store where they are resold. The retailer owns a warehouse for their European operations that is entirely dedicated to returns, which is located in Spain. PostNL and UPS transport the returns as Third Party Logistics Provider (3PL). Both 3PLs have several collection points and distribution centers in the Netherlands. Products purchased and returned through other franchise retailing channels like Zalando or AboutYou are excluded from the data as this is less accurate than the data owned by the fashion company.

Data specifications of the base case

The data provided by the client retailer entails return data for a whole business year in 2020. The data set contains 1735 return orders from different customers in the Netherlands. The number of returned items per order is also known, resulting in 6388 returned items in the base year. The frequency of return methods used was 92.45% by collection point (1603 packages), 6.11% by home pick-up (106 packages), and 1.44% by brick-and-mortar returns (26 packages). As said, the number of items per return package is also known. In total, 5912 items were transported by collection points, 407 by home pick-up, and 69 were returned at the brick-and-mortar store.

5.2. Data preparation and analysis

The data must be prepared, analyzed, and structured before being used as input for the CI. The previous chapter has provided insight into the data requirements for each variable (see section 4.4). The collected data and quality are elaborated on in this section, Appendix D provides an overview of the data.

V1. Packaging emissions

Packaging waste is only created for the retailer when the product is shipped using the return methods: collection point returns, home pick-up, and if the products are transported from the store to the warehouse. The retailer's data gives insight into which return method is used so that packaging emissions can be allocated accordingly. The retailer from the base case offers a wide assortment of apparel, so a combination of packaging materials is likely used. From the expert consultation, it follows that all products are individually packaged in a plastic polybag (Low-density polyethylene (LDPE)), and to ensure safe transport, either a cardboard box or a plastic shipping bag is used. Both packages are used often according to an expert and [191], so it is assumed that this is 50-50 in the base case. This is randomly decided in the model in Python. According to the same industry expert, most of the packaging material is sent to disposal and destroyed, and only a meager share is recycled in fashion mainly. This is partly due to the low quality of the packaging when it gets returned. In addition, the material type of returned packaging differs as almost 80% of the customers do not return their product in their original packaging [191]. These factors make the recycling of packaging more difficult. It is therefore assumed that no packaging is recycled in the base case. Whether the package is sent to a landfill or incineration is randomly assigned by the model in Python. Municipal waste treatment facilities will likely handle all packaging waste [39]. The mass of an average package is derived from literature sources, which can be found in Appendix C. The Emisison factor (EF) used for the measurement of material-specific packaging waste can be found in Appendix E under *packaging waste treatments*.

V2. Transport emissions

The data provides insight into the chosen method of return and the 3PL, the location of origin, final destination, the mass of the product, and its packaging. With these inputs, the transport emissions for each return are calculated using the distance method, considering each trip between recovery locations separately. This will improve the reliability of the calculation because each trip has different characteristics, and other transport modalities are involved. The total transport emissions of a returned product are the sum of these trips. The retailer only uses road transportation, which PostNL and UPS perform. The return methods offered by the retailer are in-store returns, collection point returns, and home pick-up. PostNL only provides home pick-ups. Products returned by customers at the brick-and-mortar store can be transported to the warehouse by PostNL or UPS. Both 3PLs have distribution centers for packages spread throughout the Netherlands. The model assumes that the parcels are transported to the nearby distribution center of the specific 3PL and, from there, are transferred to another modality to be transported to the final destination. The city's first- and last-mile transport is done by distribution vans and the long-haul trip by trucks. The distances are measured using Google Maps and implemented in Python. For home pick-up trips, it is assumed that the first address severed is of the customer, whose exact location is known, with an average pick-up trip distance of 50 km [118]. This implies that the vehicle serves 100 customers with an average distance of 0.5 km between the customers [40]. For the collection point trip, it is also assumed that the first location of the stop is the collection point of the customer, with an average trip distance between the stops of 80 kilometers [51]. For the long-distance trip, distances are measured between the distribution points of the 3PL providers and the final destination using Google Maps. No data is provided on vehicle characteristics. Assumptions are made based on the vehicles of the 3PL of the executed trip. According to [41], almost all trucks are diesel-fueled in the Netherlands, which is assumed to be the same for the base case. Based on [110], freight emission values are derived for the trucks. This study expresses the load factor based on the type of cargo transported, which determine the emissions created per tonne-kilometers. The distinction is made between light, medium, and heavy loads. The freight transported for this study falls under the light bulk and piece transport category, which corresponds to less than 0.4 kg/L in the cargo area [110]. Most distribution vans in the Netherlands are diesel-fueled, followed by petrol [41]. The values of the EF used for the different modalities are obtained from multiple databases (i.e., CO2emissiefactoren, CE Delft, BEIS). They are presented in Appendix E under *freight* *transport*. For the base case, the EF for the truck trailer light diesel is used for long-haul transportation; for short-haul transportation, the EF for vans with an average fuel type is used.

For the trip from the customer to the store and the distribution centers, statistics of Centraal Bureau voor de Statistiek (CBS) are used to specify the modality as explained in the previous chapter. It is assumed that when a customer needs to travel less than 6 kilometers to the physical store, an average EF of the slow transportation modes (bike, walking, bus, metro, tram) is used. When the customer needs to travel distances larger than 6 kilometers, an average EF for the car will provide a reasonable approximation [27, 29, 84].

V3. Warehouse and equipment emissions

The warehouse's energy consumption or rating is unknown from the retailers' data. The warehouse emissions are therefore determined according to the proposed method of [84], which is based on the warehouse area. The warehouse area for returns and the number of returns handled over a time period are obtained from client data. An EF for warehouse energy is derived from the Greenhouse Gas (GHG) Protocol database specified for a leased warehouse facility, which can be found in Appendix E. The area is multiplied with this EF and divided by the number of returns to derive the warehouse emissions per returned product. Next, the retailer has given insight into the type and number of equipment used for handling product returns at the warehouse. With this input, the equipment emissions for handling the returns at the warehouse can be determined using an EF from the database of EXIOBASE. This EF is specified for the energy grid of the warehouse location and measured in monetary values. Prices for the equipment are derived from several large equipment manufacturers or suppliers, like Toyota Material Manufacturing, Bigrentz, and AltaEquipment. The client has shared the number of returns handled in the warehouse, which will be used to derive the warehousing and equipment emissions per item. This is presented in Appendix F.

V4. Product disposal emissions

The disposal emissions are determined using the method of [84] for waste, as the client has only provided information on the mass of the products and not on which waste treatment is used. It is chosen only to limit the emissions of recovery to reselling the product and disposal to landfill or incineration emissions of the products. Particularly in the fashion industry, the most significant proportion of returned products is either resold and reused or sent to incineration or landfills. Recycling rates of textile waste, including both returns and non-returned products, in Europe is below 1% [122, 52]. Considering the proportion of recycled items from returned products, it is assumed that a value close to zero is likely. Little information is known about the exact number of recycled items, which is also true for items that get repaired. Multiple industry experts confirm this lack of information and transparency in business operations. In addition, [166] studied the environmental footprint generated by recycling clothes in Japan. They concluded that the GHG emissions of recycling a clothing product highly depend on the type of recycling method chosen, the type of product that is recycled, and which sort of product it will be recycled into. So, estimating the environmental impact of recycling a clothing item is very complex and surrounded by a lot of uncertainty, which is even more difficult as there is little data available and it is highly product dependent. This implies that for including recycling as a recovery option in this base case, the additional assumptions that need to be made will likely be insignificant and inaccurate. It is therefore chosen only to focus on reselling/reusing the product (direct recovery) and disposal to landfill or incinerated (process recovery). This research assumes, therefore, that recovered, recycled, or repaired parts are stored and resold again if not mentioned differently, and the features that cannot be retrieved are eventually redirected to landfills or incineration.

Waste-treatment specific EFs for clothing are selected from the BEIS database from DEFRA, presented in Appendix E under *Waste treatment*. This gives insight into the landfill-, reuse-, and incineration of kgCO2-equivalent emissions per kg of clothing, including the collection and transport to the distribution facility [43]. There is no specific data available for determining the frequency of disposal treatments. Therefore, insights from an expert consultation with a fashion warehouse manager and an expert in the field of textile recycling are gathered to gain more understanding of this matter, combined with findings from [4]. Most items are reused and resold again, but there is also a share that gets sent to landfill or incinerated. This has led to the following allocation for the base case: it is assumed that 80% of the products are resold and reused, 10% are sent to landfill, and 10% are sent to incineration. The model assigns the waste treatment to the return orders based on a random assignment to improve reliability.

V5. Brick-and-mortar emissions

No data is provided on the store's energy consumption by metered data. This can be approximated using the energy label and the area of the retail store. Each label corresponds to a maximum primary fossil energy consumption in the Netherlands in $kWh/m2/year$, with A the best and G the worst performance [155]. Following the energy rating of the store, which is C, the value of the maximum primary fossil energy consumption in the Netherlands is obtained. This number is multiplied by the area of the store in $m2$, which estimates the store's energy consumption in kWh for a year. The total emissions are allocated to the total number of products handled in-store for the year, so items in inventory, sold, and returned in-store are considered. As no specific data is available on the time spent at the store for each item, it is assumed that the total emissions are equally distributed over the total number of products handled in-store in one year. These values can be found in Appendix D.

V6. Transport costs

The data provided by the external client for transport costs are the customer's location, the initial point of recovery, and final destination, the transported mass, and the 3PL used. From [41], it is found that for long-haul transport, diesel trucks are used for short-haul distribution vans that are mostly diesel- and sometimes petrol based. Based on these inputs, conversion factors of the Netherlands Institute for Transport Policy Analysis (KiM) are used [187]. This modality-specific conversion factor includes fixed, variable, staff, mode characteristics, and general operating cost elements. The most recent report uses fuel prices from 2018 [187]. Based on the type of vehicle used for the transport, a mode-specific conversion factor in [euro/kg-km] is multiplied by the distance driven in kilometers and the parcel mass in kilograms to derive the transport costs per kg returned product. The distance driven is already determined for the measurement of the transport emissions. This is presented in Appendix F. For the base case, the costs for a diesel truck for transporting light bulk goods are used; for short-haul transport, the costs of an average fueled van are used.

V7. Labor costs

The labor costs are calculated by the sum of receiving, inspecting, and restocking products and any additional overhead expenses. Data is provided on the number of warehouse employees. Further data is found from literature, governmental reports, and expert consultation. Expert consultation has given insight into the total activity time of a return handling in-store and at warehouses on average. This activity is quite labor-intensive as the product needs to be inspected to determine if it is good enough to be restocked. The warehouse's labor costs are determined based on the hourly return rate and the average time needed to take a return [89]. Further, the employee overhead expenses depend on the country where the labor is performed and is retrieved from EuroDev. The total costs per product return at the in-store are calculated by the labor cost per hour, including the overhead expenses, which must be multiplied by the time spent fulfilling the tasks. The minimum wages are derived from Rijksoverheid, and the overhead costs are found in the database of Eurodev.

V8. Warehouse and equipment costs

Data on the warehouse size, the warehouse location, the leasing structure, the number of equipment, and the type of equipment is provided by the retailer. The missing component for calculating the costs is the warehouse leasing costs on an annual basis. For the warehouse leasing costs, data sources from Statista provide the average warehouse rental costs per square meter for a specific location [173]. Additional consultation with a fashion warehouse manager has provided insight into the most commonly used type of equipment and loading capacity for retailer warehouse operations to specify the equipment type further. Data from secondary resources of large equipment manufacturers or suppliers, like Toyota, Bigrentz, and AltaEquipment, are used to estimate the costs of the equipment.

V9. Recovery costs

The recovery costs of a product depend on the disposition method chosen, the mass of the product, the disposition fees, and storage costs. There is no data on the retailer's disposition costs, so secondary sources from European reports, expert consultation, and literature are used to collect data. It is assumed that municipal waste treatment facilities handle all waste. Country-specific disposition fees per kg can be retrieved from [69] and supplemented by [53]. The mass of a product is known so that the disposition costs can be accurately determined for each item. Expert consultation and literature have been used to assess product reuse/redistribution costs. This is assumed to be half the cost of return handling as the product needs to be inspected and stored, so resorting and repackaging activities are considered the most cost-intensive activities. The cost of return handling is derived from a study of [89]. The cost of packaging waste per item can be measured using European reports' disposition and recycling fees. These costs are measured in euros/kg, so the mass of the packaging is another input for this measurement and can be found in Appendix C.

V10. Brick-and-mortar store costs

The brick-and-mortar store location, store area, and leasing structure are known. To determine the rental costs, an estimation is made using the report of [38]. This report has provided a detailed insight into the rental fees for shopping areas in the store's location and is used as a source for cost estimation. Data is collected on the number of products handled in stores in the considered year and the number of returned items. Based on this data, a fraction of this cost can be allocated to an item.

5.3. Design of the CI

In this section, the CI to measure the environmental and economic impact of product returns on a company's performance is created using the collected data as input. The model is designed using the data from the base case. The different return methods are also analyzed separately for the base case. This section follows the construction structure of the CI, as outlined in section 3.3.

5.3.1. Phase 1. Selection of the indicators

Ten variables are aggregated into the final value of the CI. Variables 1-5 are categorized as environmental variables, and 6-10 as economic performance variables. The data is collected, prepared, and analyzed for the base case. The raw values of the CI are presented for the overall performance of the fashion retailer of the base case. Also, the performance of the different return methods for this retailer is analyzed and measured, which can be seen in Table 5.1. The red values indicate the highest value of the return methods on that indicator, which is not desired. The green numbers correspond to the lowest, and thus most desirable in terms of performance, values of a return method for an indicator.

Table 5.1: Raw indicator values for each return method in the base case, source: (Author)

	V_1 [kgCO2e/ returned product]	V_2 [kgCO2e/ returned product]	V_3 [kgCO2e/ returned product]	V_4 [kgCO2e/ returned product]	V_5 [kgCO2e/ returned product]	V_6 [euro/ returned product]	V_7 [euro/ returned product]	V_8 [euro/ returned product]	V_9 [euro/ returned product]	V_{10} [euro/ returned product]
Base case overall performance	0.075	32.217	1.092	0.012	0.712	0.230	12.379	5.096	0.523	1.903
Return method 1. Home pick-up	0.077	23.721	0.624	0.005	0.784	0.432	7.076	4.721	0.280	2.093
Return method 2. In-store	0.013	42.567	1.559	0.016	0.642	0.073	17.666	5.470	0.755	1.896
Return method 3. Collection point	0.078	32.592	1.118	0.010	0.710	0.217	12.673	5.117	0.539	1.896

With V_1: packaging emissions, V_2: transport emissions, V_3: warehouse and equipment emissions, V_4: product recovery emissions, V_5: brick-and-mortar emissions, V_6: transport costs, V_7: warehouse and equipment costs, V_8: labor costs, V_9: recovery costs, V_{10}: brick-and-mortar costs.

How the environmental and economic impact of a return method can be calculated
Table 5.1 presents for each return method the raw value per returned product for each indicator based on the data of this retailer. This is used to calculate the total environmental and economic impact per return method. For the environmental and economic dimension, the raw values of all indicators are summed, as seen in Table 5.2. It can be seen that in-store returns have both the highest environmental impact and the largest costs. Contrary, home pick-ups have lower kgCO2e per returned product as well as the cost per returned item. The collection point returns have values that are in between the home pick-up and in-store methods.

Table 5.2: Summation raw values of the indicators for the environmental and economic impact per return method, source: (Author)

	Environmental impact [kgCO2e/ returned product]	**Economic impact** [euro/ returned product]
Base case overall performance	34.108	20.132
Return method 1. Home pick-up	**25.211**	**14.602**
Return method 2. In-store	**44.797**	**25.678**
Return method 3. Collection point	34.509	20.443

5.3.2. Phase 2. Normalization of the indicators

The data from Table 5.1 is normalized using the adapted rescaling method proposed in Equation 4.1, where all variables are normalized between 1 and 2. 1 represents the least desired value in Table 5.3, and 2 is the best in terms of performance.

Table 5.3: Normalized indicator values for each return method in the base case, source: (Author)

	V_1	V_2	V_3	V_4	V_5	V_6	V_7	V_8	V_9	V_{10}
Base case overall performance	1.055	1.549	1.499	1.345	1.504	1.563	1.499	1.499	1.487	1.504
Return method 1. Home pick-up	1.024	2.000	2.000	2.000	1.000	1.000	2.000	2.000	2.000	1.000
Return method 2. In-store	2.000	1.000	1.000	1.000	2.000	2.000	1.000	1.000	1.000	2.000
Return method 3. Collection point	1.000	1.529	1.471	1.507	1.520	1.598	1.471	1.471	1.454	1.520

With V_1: packaging emissions, V_2: transport emissions, V_3: warehouse and equipment emissions, V_4: product recovery emissions, V_5: brick-and-mortar emissions, V_6: transport costs, V_7: warehouse and equipment costs, V_8: labor costs, V_9: recovery costs, V_{10}: brick-and-mortar costs.

5.3.3. Phase 3. Weighting of the indicators

In this stage, experts are requested to express relative preferences between each pair of variables to derive the weights using the Analytical Hierarchy Process (AHP) method. The experts operate in the fashion industry and have relevant knowledge and expertise in the retailer's objectives, criteria being evaluated, and the decision-making context. The experts are selected independently to avoid biases, and the perspective is explicit upfront. The pairwise comparison matrix presented in Table 5.4 is derived from these expert weighting. The scores should be interpreted as V_2 (transport emissions) is believed to be four times more preferred than V_1 (packaging emissions).

Table 5.4: Reciprocal comparison matrix, source: (Author)

	V_1	V_2	V_3	V_4	V_5	V_6	V_7	V_8	V_9	V_{10}
V_1	1	1/4	1/2	1/2	1	1/4	1/3	1/2	1/2	1
V_2	4	1	2	2	3	1	1/2	2	2	6
V_3	2	1/2	1	3	2	1/2	1/2	1	2	3
V_4	2	1/2	1/3	1	1/3	1/2	1/3	1/2	1/2	3
V_5	1	1/3	1/2	3	1	1/2	1/4	3	2	1
V_6	4	1	2	2	2	1	1/3	2	2	3
V_7	3	2	2	3	4	3	1	3	6	2
V_8	2	1/2	1	2	1/3	1/2	1/3	1	2	1
V_9	2	1/2	1/2	2	1/2	1/2	1/6	1/2	1	2
V_{10}	1	1/6	1/3	1/3	1	1/3	1/2	1	1/2	1

With V_1: packaging emissions, V_2: transport emissions, V_3: warehouse and equipment emissions, V_4: product recovery emissions, V_5: brick-and-mortar emissions, V_6: transport costs, V_7: warehouse and equipment costs, V_8: labor costs, V_9: recovery costs, V_{10}: brick-and-mortar costs.

Next, the weights are determined in Table 5.5. This is done using Equation 4.5 and Equation 4.6. The total sum of the weights is equal to 1.

Consistency check

The Consistency Ratio (CR) is calculated using Equation 4.7. A value of 1.49 is taken as the baseline for the acceptable level of consistency for the CR of this CI [142]. The consistency check with λ_{max} = 10.942 results in a CR value of 0.070. This is below the threshold value of 0.10, implying an acceptable consistency in the comparative judgments [167].

5.3.4. Phase 4. Aggregation of the indicators

The value of the different return methods in the CI are calculated using the normalized value and the weights obtained from the previous phases by applying the multiplicative aggregation approach in Table 5.6. A higher value for the CI indicates better performance. The analysis shows that the in-store return method scores lowest, visualized with the red color. The home pick-up method performs better than the other return methods and is represented in green. The base case consists of the combined value of all return methods to provide

Table 5.5: Weights derived by AHP, source: (Author)

	Weight
V_1	0.044
V_2	0.158
V_3	0.104
V_4	0.060
V_5	0.085
V_6	0.134
V_7	0.228
V_8	0.075
V_9	0.063
V_{10}	0.048

insight into the retailer's overall performance. If the company would implement an action, measure it with this setting on the CIs, and obtain a higher value for its aggregated CI, this would mean that a better performance is obtained. If the score of the CI would be decreased after implementation, this would imply that a lower performance is gained. As can be seen, the base case overall performance and the collection-point returns are relatively close. This is as expected, as the returned products are for 92.45% performed with the collection-point method for this data set, and the overall base case performance is the average of the return methods.

Table 5.6: Aggregated CI scores base case, source: (Author)

	CI score
Base case overall performance	1.482
Return method 1. Home pick-up	**1.613**
Return method 2. In-store	**1.241**
Return method 3. Collection point	1.479

5.3.5. Phase 5. Post-analysis evaluation of the CI

The post-analysis evaluates the robustness and reliability of the constructed CI. Therefore, several uncertainty triggers were identified during the construction of the model (X_1 weighting method, X_2 aggregation method, X_3 input data), see subsection 4.3.5. The insight should be obtained if- and to what extent different construction methods or changes in the input data would lead to significant changes and differences in final values of the CI. Therefore, the uncertainty sources are analyzed, and their correlation with the model results obtained in this chapter is checked. Context scenarios should be developed to gain insight into the sensitivity of the construction methods and input data of the CI.

5.4. Conclusions performance measurement

This section concludes and gives insight into the performance scores the CI obtained. First, the environmental and economic impact of the return methods before aggregation is analyzed and compared with the outcomes of the aggregated scores, followed by an evaluation of the aggregated values of the different return methods and their performances.

Performance scores before and after multi-dimensional aggregation

In Table 5.7, the scores of the return methods are visible for each dimension separately. The indicators of the environmental and economic dimensions are weighted and aggregated but not combined to a multi-dimensional CI yet, which provides insight into how each method performs before aggregation. A higher value indicates better performance and vice versa. In-store returns perform lowest on the environmental scores; collection point returns perform somewhat better, and home pick-ups score best on environmental performance for this company. The economic scores show that home pick-up performs best, followed by the collection point returns with a relatively small difference in performance score. In-store returns have a relatively large difference in the economic performance with the other return methods, indicating that this method has worse economic performance than the other methods. As seen in Table 5.6, the same conclusions can be drawn when the dimensions are aggregated to reflect on the overall performance of a company. Home pick-up outperforms the other methods, followed by collection point returns, and in-store scores are the lowest based on this data set.

Table 5.7: Environmental performance score and economic performance score of the return methods, source: (Author)

	Environmental performance score	**Economic performance score**
Base case overall performance	1.334	1.513
Return method 1. Home pick-up	**1.545**	**1.588**
Return method 2. In-store	**1.150**	**1.260**
Return method 3. Collection point	1.339	1.504

Base case return methods performance

To better understand the differences in performance of the return methods, Figure 5.1 is created. This radar chart presents the values of each return method on the indicator after the assignment of the weights. The orange line depicts the value of a return by home pick-up, the blue line represents in-store returns, and the green line displays returns through collection points. The indicators are defined on the spokes of the radar. For each indicator, better performance is obtained when the value is higher, corresponding to values more on the outside of the axis in the radar. Values closer to the center are less preferred in terms of performance. The radar shows that for home pick-up, the values are often at the outside points of the radii compared to the other return methods. The green line from the collection point returns is mainly found between the different methods' values. The in-store returns scores are often the lowest compared to the other methods on the indicators but also show some outliers indicating high performance. An outlier for in-store returns is visible for indicator V_6, transport costs. The in-store return method performs thus well on this indicator compared to the other return methods. An explanation for this is that no costs are accounted to the company when the customer makes the trip to return the item to the store. However, there still are transport costs created with this return method. The data shows that multiple products returned in-store are transported to the warehouse in Spain and not resold in-store. This partly explains why this alternative has relatively high transport emissions (V_2). The transport emissions for in-store returns include, besides the optional trip from the store to the warehouse, the emissions created by the customer to the store and back home are accounted for in this metric. This creates relatively many transport emissions per return. Home pick-up performs much better on the transport emissions per return due to the more efficient transport networks of 3PL, where shipments are consolidated. However, this return method is more costly for the company. This is because the transport costs are determined using the distance-based method, where the costs per kilometer with distribution vans are slightly higher than with modes for long-haul distances. The home pick-up alternative has more kilometers per return driven with vans than the other return methods. The warehouse and equipment costs for a home pick-up are also less costly for a return. An explanation is that relatively many products collected with home pick-up are resold in-store, causing the highest brick-and-mortar costs and emissions in V_{10} and V_5, respectively, relative to the other methods.

Looking at the labor costs V_8; the in-store method performs worst than the other methods. An explanation for this is that the products are first checked in the brick-and-mortar store, and multiple products are transferred to the warehouse afterward, creating double labor. The labor wages for employees in the Netherlands are relatively higher but do not outweigh the costs of labor when a product is handled at a warehouse. Products dealt with at the warehouse require relatively much time and activities, increasing the labor cost per return. So, as most products from home pick-up are transported to the brick-and-mortar store, they create relatively lower labor costs. As seen, in-store returns score best on packaging emission V_1, which is expected as packaging is not needed for transporting the item to the brick-and-mortar store. Packaging material is needed for each return using online return methods (i.e., home pick-up and collection point), creating emissions. However, a return using the in-store return method also creates packaging emissions because the data shows that some products are transported from the brick-and-mortar store to the warehouse, still requiring packaging. Warehouse and equipment emissions are created when products have a final destination in the warehouse. For home pick-up, this value is best amongst the other methods as a larger share of these returns gets transported to the store, lowering the warehouse and equipment emissions on the product return level. The other methods have higher shares of products ending at the warehouses, leading to higher values for these warehouse and equipment emissions.

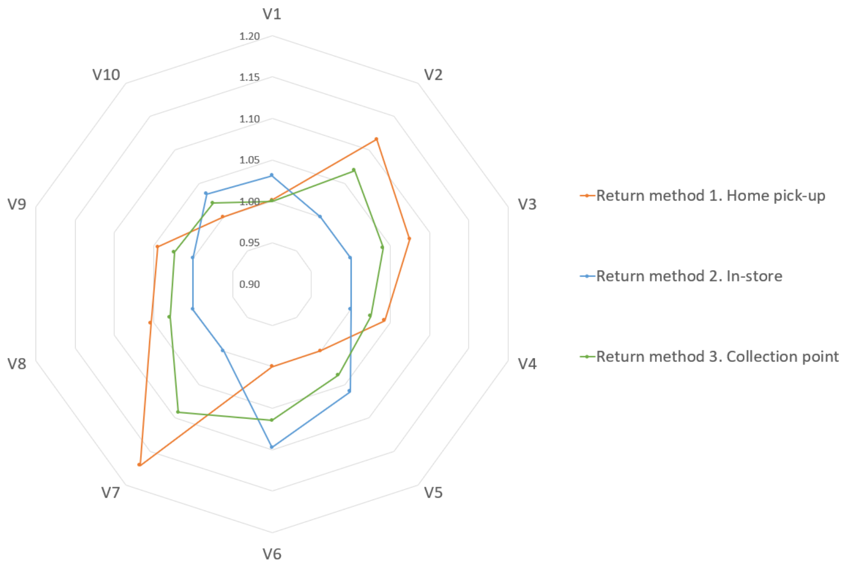

Figure 5.1: Radar chart of the different return methods in the base case, source: (Author)

With V_1: packaging emissions, V_2: transport emissions, V_3: warehouse and equipment emissions, V_4: product recovery emissions, V_5: brick-and-mortar emissions, V_6: transport costs, V_7: warehouse and equipment costs, V_8: labor costs, V_9: recovery costs, V_{10}: brick-and-mortar costs.

5.5. Main findings chapter 5

This chapter has answered the question *'How can the current state of a company's performance be measured using the CI?'* To answer this question, the CI is developed using data from a fashion retailer, where the environmental and economic performance of the different return methods were analyzed. A CI score is obtained that represents a company's combined environmental and economic performance for each return method, where a higher score represents a better performance. A company can only consider the environmental or economic impact of a return method on its performance by only including the set of indicators of one dimension. An in-depth evaluation of how each return method scores on the indicators shows valuable insights into how- and why each method differs in performance. This showed a company's relevance in comparing scores with a reference, which is currently lacking in the CI.

6 Design

This chapter designs a benchmark for companies to compare their performances with. It followed from the previous chapter that with the Composite Indicator (CI), the performance of a company can be measured, but insights lack on how good the companies' current performance is relative to a reference. The European Union (EU) sets sustainability objectives to combat climate change [59]. As companies need to comply with legislation and regulations of the EU, they need to know how far they are in reaching these sustainability targets. Therefore, this research intends to develop a benchmark which companies can use to evaluate their performances and give them crucial insights to improve their sustainability and comply with EU targets. The benchmark will be developed using the PESTLE framework, explained in section 6.1. Next, the benchmark design is presented in section 6.2, followed by its set-up. Following, the benchmark will be integrated into the CI and tested with the base case in section 6.3. It will be verified how- and whether the model can demonstrate its intended purpose, which is reflected in section 6.5. As a result, this chapter answers sub-question 4e) *How can the constructed CI be verified?*

6.1. PESTLE analysis

The benchmark is designed using the PESTLE analysis (Political (P), Economic (E), Sociological (S), Technological (T), Legal (L), and Environmental (E)) [148, 198]. This analysis is an extended version of the original PEST (Political (P), Economic (E), Sociological (S), Technological(T)) analysis. The analysis helps identify and understand external environmental factors in a dynamic environment and identifies risks [198]. The analysis serves as a tool to ensure a complete overview of all these contextual factors is created [148, 109]. Scientific research and expert consultation identify the factors, trends, and shifts that drive developments. Examples are stricter environmental policies, more conscious shopping behavior, improved efficiency of equipment and modalities, and availability of recycling alternatives [145, 23, 119, 84].

6.2. Design benchmark

This benchmark is defined according to specific targets for each indicator driven by Legal (L) and Policy (P) factors from the PESTLE criteria. European companies should comply with their performances with legislation and policy-making decisions, which therefore drive company improvements. The benchmark is set for the year 2030. This will represent the shorter-term goals of a company in its net-zero journey for 2050, which are more tangible and more accessible for companies to achieve as it is less than a decade away. Also, shorter-term goals allow companies more flexibility in their strategies for achieving them. Values for these standards are found through reports, official publications, and, optionally, expert consultation. These values should be defined in the same unit of measurement as the actual indicators. The standards for each indicator are applied to the base case data presented in section 5.1. So, for example, the original value of the indicator for transport emissions in the base case will be adjusted to conform to the reduction target of 55% from the base year to the target year. Next, it needs to be mentioned that making any accurate assumptions on the benchmark costs for 2030 is impossible, as this is highly surrounded by uncertainty and external factors, which are confirmed by experts from the industry. Many factors affect the costs (i.e., inflation, innovations, potential crisis, war), making the expenses not accurately estimated for the benchmark, but can be looked into in scenarios. For this reason, it is chosen to apply the base case costs for the economic benchmarks in this research. This assumption will be reflected in the discussion.

6.2.1. Description of the benchmark

The benchmark is defined according to specific targets for each indicator driven by Legal (L) and Policy (P) factors from the PESTLE criteria. European companies should comply with their performances with legislation and policy-making decisions and drive company improvements. The European Commission (EC) defines no specific targets and legislation for packaging currently. E-commerce packaging should improve its environmental impact by reducing the amount of material used, using sustainable materials that are recyclable or reusable, and being responsible for waste management. The EC proposal on packaging and waste is not accepted [64] yet. The proposal's objectives are threefold: packaging should be made out of recycled materials, minimizing waste by 15% in 2040, and increasing the recycling and reuse rate of packaging. The packaging recycling rate for cardboard should be 85% and for plastic 55% in 2030. Further, landfill should decrease to 9.6% [64, 68]. The base case assumes that a combination of packaging materials like plastic Low-density polyethylene (LDPE) and recycled cardboard is used. Further, the waste treatments for recycling and landfill are defined according to the target values of 85%, 55%, and 9.6%, respectively. The remaining packaging material is combusted.

The target value for transport emission reduction by the EC is set at 55% by 2030 compared to the base year 1990, which was accepted in 2020. The EU in the 'Sustainable and Smart Mobility Strategy' report supports the feasibility of this benchmark value [70]. Assuming a linear reduction rate, this would mean a yearly Greenhouse Gas (GHG)-emission reduction of 1.57% from 1995-2030. The benchmark target in this research is set at this value for 2030 to comply with the EC target values.

The point of departure for the improved environmental impact of warehousing and in-store building emissions is using renewables. The EC has put a benchmark of 32% of renewable energy sources in buildings by 2030, which will be the target value for the benchmark in this research [61]. Electricity produced by renewables should power warehousing equipment as well in 2030.

Several strategies are proposed to lower waste emissions in the fashion sector, including developing ecodesign measures, guidance on waste management and circular businesses, and promoting waste treatments. The EC proposes Extended Producer Responsibility (EPR) for 2025 for textiles. With this, a closed-loop system is upgraded with recycling and reusing as preferred options; disposition to landfills should be reduced to a minimum as it generates the highest negative environmental impact according to the waste hierarchy [63, 68, 65]. The disposed of and not separated products are treated as municipal solid waste [111]. The EC has set targets to reduce the GHG emissions of municipal waste by 30% in 2030 [65]. Considering this, the benchmark value for the variable disposition emissions in this research is set to a limitation of incineration and landfill to 1% by 2030 and a reduction of overall disposal emissions by 30%.

6.3. Benchmark testing

The benchmark development follows the same construction steps outlined in the previous chapter section 5.3 for the normalization and aggregation of the values. The weighting is done by Equal Weights (EW) instead of Analytical Hierarchy Process (AHP). It is decided that all indicators should have equal weights, as subjectivity is not preferred here. This also ensures that the preferences of companies cannot distort the benchmark values and the importance of all standards remains equal for all users of the CI. This will increase transparency on the benchmark values and is confirmed by industry experts. EW assigns equal weights to the indicators. As the total sum of the weights should equal 1, the individual weights of the 10 variables are 0.1.

The raw data is expressed in Table 6.1. The target reductions for the benchmark are applied to the data of the overall base case. For the return methods and the base case overall performance, the same data is used as presented in the previous chapter. In this table, the lowest values are marked red for an alternative on the indicator, and the green values are perceived as the best possible value from the set of alternatives on that indicator.

Next, normalization is done using the rescaling method proposed in Equation 4.1, shown in Table 6.2. All indicators are converted to a range between 1 and 2, where 2 represents the best value and 1 the lowest [204]. Weighting is applied to the indicators, and aggregation leads to Table 6.3. The CI scores should be interpreted the same as in the previous chapter, where a higher value of the CI represents better performance and a lower value indicates worse performance. As can be seen, the benchmark performs highest in terms of performance. The best performance among the alternatives is marked in green, and the lowest performance of the alternatives is marked in red. The results show that in-store returns score lowest among the alternatives, and the home pick-up score best. The overall performance of the base case, which is the combined value of all three return methods, scores in between. As can be seen, the benchmark performs highest in terms of performance.

In Table 6.1 and Table 7.2: V_1: packaging emissions, V_2: transport emissions, V_3: warehouse and equipment emissions, V_4: product recovery emissions, V_5: brick-and-mortar emissions, V_6: transport costs, V_7: warehouse and equipment costs, V_8: labor costs, V_9: recovery costs, V_{10}: brick-and-mortar costs.

Table 6.1: Raw indicator values base case with the benchmark, source: (Author)

	V_1 [kgCO2e/ returned product]	V_2 [kgCO2e/ returned product]	V_3 [kgCO2e/ returned product]	V_4 [kgCO2e/ returned product]	V_5 [kgCO2e/ returned product]	V_6 [euro/ returned product]	V_7 [euro/ returned product]	V_8 [euro/ returned product]	V_9 [euro/ returned product]	V_{10} [euro/ returned product]
Benchmark	0.016	**14.498**	0.743	0.007	**0.484**	0.230	12.379	5.096	0.523	1.903
Base case overall performance	0.075	32.217	1.092	0.012	0.712	0.230	12.379	5.096	0.523	1.903
Return method 1. Home pick-up	0.077	23.721	**0.624**	**0.005**	**0.784**	**0.432**	**7.076**	**4.721**	**0.280**	**2.093**
Return method 2. In-store	**0.013**	**42.567**	**1.559**	**0.016**	0.642	**0.073**	**17.666**	**5.470**	**0.755**	**1.715**
Return method 3. Collection point	**0.078**	32.592	1.118	0.010	0.710	0.217	12.673	5.117	0.539	1.896

Table 6.2: Normalized values base case with the benchmark, source: (Author)

	V_1	V_2	V_3	V_4	V_5	V_6	V_7	V_8	V_9	V_{10}
Benchmark	1.950	2.000	1.873	1.860	2.000	1.563	1.499	1.499	1.487	1.504
Base case overall performance	1.055	1.369	1.499	1.345	1.238	1.563	1.499	1.499	1.487	1.504
Return method 1. Home pick-up	1.024	1.671	2.000	2.000	1.000	1.000	2.000	2.000	2.000	1.000
Return method 2. In-store	2.000	1.000	1.000	1.000	1.473	2.000	1.000	1.000	1.000	2.000
Return method 3. Collection point	1.000	1.355	1.471	1.507	1.246	1.598	1.471	1.471	1.454	1.520

Table 6.3: Aggregated CI scores with benchmark, source: (Author)

	CI score
Benchmark	1.710
Base case overall performance	1.430
Return method 1. Home pick-up	**1.568**
Return method 2. In-store	**1.209**
Return method 3. Collection point	1.427

6.4. Conclusions performance measurement with the benchmark

The performance of the different return methods and the base case are compared relative to the benchmark, which is the target performance. Literature has shown that this can be done by determining the relative performance RP or the performance gap M, as found in section 3.5. Relative performance is the actual and target performance ratio, calculated with Equation 3.1. The performance gap represents the difference in performance between a company's actual and target performance, which is the benchmark and is calculated by Equation 3.3, using the data from Table 6.3. The best performance is achieved when the values of all indicators are minimized, so a lower value for the performance gap M means a better performance score [49]. As seen in Table 6.4, the performance gap with the benchmark is the smallest for the home pick-up return method and the largest with in-store returns. The relative performance expresses the same, which shows how each method scores in terms of its ratio with the benchmark.

More in-depth insights can be found by plotting the weighted indicator values in a radar chart, visualized in Figure 6.1. The indicators are defined on the spokes of the radar. For each indicator, better performance is obtained when the value is higher, corresponding to values more on the outside of the axis in the radar. Values closer to the center are less preferred in terms of performance. The blue line represents the benchmark values. The benchmark outperforms the alternatives on the environmental indicators, as the benchmark values are mainly on the outsides of the radii compared to the others. This is expected, as the benchmark expresses target values for environmental performances.

The overall base case performance has a performance gap of 0.280. Comparing the base case values with the benchmark in Figure 6.1, it can be seen that the benchmark outperforms the base case in almost all

Table 6.4: Relative performance and performance gap base case with the benchmark, source: (Author)

	Relative performance RP [%]	**Performance gap M**
Benchmark	100%	0.000
Base case overall performance	84%	0.280
Return method 1. Home pick-up	**92%**	**0.142**
Return method 2. In-store	**71%**	**0.501**
Return method 3. Collection point	83%	0.283

indicators. The largest gap, and thus performance difference, between the benchmark and base case is in the environmental indicators. This is in line with the expectations, as in the base case, not much has been done to improve the company's environmental performance. The gap between the base case and environmental indicators is smaller for the economic indicators, resulting from the different weights. The weights, especially the transport cost (V_6) and warehouse and equipment costs (V_7), for the base case, are higher compared to the weights assigned by EW. For the benchmark, it was chosen to apply EW to reduce subjectivity in the weights, improving the transparency of the benchmark. The weights assigned with AHP lead to higher weights, resulting in better performance on these indicators. However, this effect is outweighed by the aggregated performance of the benchmark, which shows a better overall performance than the base case.

The home pick-up return method outperforms the benchmark on V_2 and V_3: transport and warehouse and equipment emissions. This is a logical result of the different weights that are used. For the economic indicators, the benchmark performs moderately, which is also not an unexpected outcome as EW is applied. Another outlier is the warehouse costs in V_7. All return methods perform better on this indicator relative to the base case. With AHP weighting, the experts have assigned relatively higher weights to this indicator than the lower weight assigned to this indicator by using EW in the benchmark. This is in line with the expectations.

The low CI score of in-store returns relative to the other alternatives is observed in the chart as well. The green line, representing the in-store returns, is mainly inside the radii, indicating lower performance. In-store returns score only better on V_6 on performance compared to the benchmark. This is in line with the findings from the previous chapter. Here, it was found that in-store returns have relatively low transport costs relative to the other methods, and the benchmark uses the transport cost value of the overall base case performance.

The observations found align with the observations from the performance analysis in section 5.4. Therefore, this section only gives a concise evaluation of the difference, and underlying reasons, between the return methods. It is essential to observe that the ranking of the return methods has remained the same before- and after the benchmark implementation in the model. This confirms the reliability of the model's output. The change in scores of the CI compared to Table 5.6 is as expected as an alternative is added to the CI.

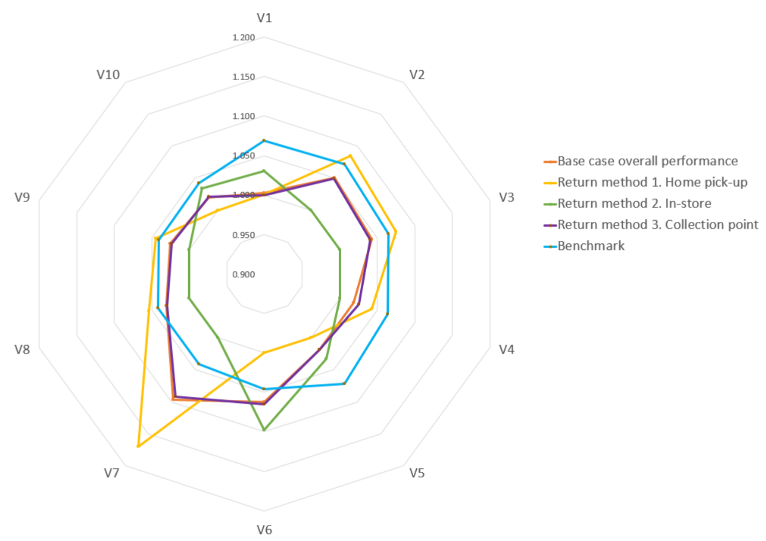

Figure 6.1: Radar chart base case with the benchmark, source: (Author)

6.5. Verification

Verification examines the question, *'Is this the right model?'*, in other words: how can it be proved that it is possible to find with this model what we want to understand? This question is addressed by thoroughly reading the model structure and its implementation to see whether this accurately represents the conceptual design and the expected outcome [7, 104]. Additionally, a framework is introduced as a tool to verify the reliability of the model outputs.

Before verification of the model, it is checked whether the conceptual model represents all essential elements to serve its purpose and requirements [181]. The conceptual model (see chapter 4) is iteratively built and continuously reviewed with multiple independent experts. These reviews served as inspection moments to verify the conceptual model's completeness and the assumptions made.

A structured walk-through verifies the model with a critical evaluation of the model's equations and formulation [104]. First, it is checked whether all variables are correctly implemented and formulated in the model. Each variable is isolated, and the calculation steps and unit of measurement are inspected. Particular consideration was given to checking the transportation emissions- and costs, as this consisted of multiple transport modalities with different characteristics that affect the calculation output. After each variable was checked, the different input values of the parameters were checked with their sources to ensure they were correctly implemented in the code. Next, the building of the CI is inspected. This is done for each construction phase separately. The selection of variables was already checked. Next, the normalization is inspected, which was done by using simple dummy data. The model calculations of normalization were compared to calculations done by hand, which verified this phase. Additional attention is paid to verifying the weighting method. The weighting method, AHP, is subjective and, therefore, has a higher risk of inconsistency [160]. To verify the weighting in this model, the group of experts assigned weights was between the recommended number of 3-7 experts. Also, clear instructions were provided for these experts to express the perspective from which they assigned the weights. The latter is particularly useful in understanding and preventing potential bias from the perspective from which experts assign weights. Besides, a consistency check is carried out that examines the reasonability of the weight scores and ensures that these represent an acceptable level of consistency [167]. This consistency check contributes to the verification of the model and its accuracy. Lastly, the aggregation of the model was checked by first checking the equations; next, the same dummy data was used to compare by-hand calculation with the models' output.

Last, the reliability of the model's output was verified [104]. Therefore, the PESTLE framework is introduced as verification to ensure the model can answer what we want to know: to gain insight into the company's performance relative to a benchmark. To ensure that the conceptual description of the benchmark is accurate and is developed by independent criteria, the PESTLE (Political (P), Economic (E), Sociological (S), Technological (T), Legal (L), and Environmental (E)) analysis is used [148, 198]. PESTLE is an internal verification tool for the benchmark design used to help to verify the model. The benchmark's description, criteria, and set-up were verified using expert consultation. Special care was given to the weighting method; it was decided in cooperation with industry experts to assign weights according to equal weighting to increase transparency and reliability of the weights when comparing the benchmark sector-wide (EW). Next, it was checked if the benchmark was correctly implemented in the model. This is done by inspecting the model's output by testing and evaluating the results generated after implementation of the benchmark on the base case performance of the CI. Performance analysis tools were identified from the literature, which was used to verify these outputs and gather insights into the needed information. The analysis showed plausible results, which were in line with the expectations and set-up of the benchmark. The previous chapter has already created data on the company's measurement, which was used to verify the benchmark models' output. This benchmark testing did additional verification of the model's output, as it was found that the ranking of the different alternatives remained the same before and after the implementation of the benchmark. So, the model's output with the benchmark generates reliable results and is successfully verified.

6.6. Main findings chapter 6

In this chapter *'How can the constructed CI be verified?'* was answered. This is done through a structured walk-through to inspect the correctness of the models' structure, implementation, and formulation and see whether the model represents the conceptual design and expected outcomes [104]. First, the variables were inspected and checked on their calculation and dimensions. Second, the equations and formulation of each phase of the CI was reviewed. Thirdly, the reliability of the model's output and set-up of the benchmark was inspected. The benchmark's set-up was verified using the verification framework PESTLE and through expert consultation. Next, it was checked whether the benchmark was implemented correctly to verify the reliability of the model's output. The benchmark was tested using benchmark techniques from the literature, which showed plausible results aligned with the expectations, and no surprises were found. The model's output showed that the model could find what needs to be understood, and the CI can be successfully verified.

7
Evaluate

In this chapter, scenarios are designed to test and validate the model. The previous chapter has provided a verified Composite Indicator (CI) and benchmark for fashion companies to compare their performance with. This research intends to identify areas of improvement for fashion companies in the process of product returns and gain knowledge of which return improvement strategy performs best regarding the environmental and economic impact. To validate if the model is able to identify improvement areas and understand the impact of external factors and the effects of adopting strategies to improve sustainability on the performance of a company, scenarios are designed. The previous chapter has introduced the PESTLE framework, which will be used to identify external environmental factors and to design the scenarios presented in section 7.1. In section 7.2, the scenarios are analyzed using the constructed CI. As part of this, an evaluation of the model takes place where the robustness of the model is tested. This gives insight into the model's sensitivity to changes in input data or the usage of different construction methods. Next, the performance analysis takes place where the performance of the different scenarios with the base case performance and the benchmark are compared in section 7.3. Lastly, the validation of the model is done in section 7.4. Thereby, SQ4f) *How can the constructed CI be used in practice by companies?* and SQ4g) *How can the constructed CI be validated?* are answered.

7.1. Design and set-up scenarios

Different scenarios will be designed that include strategies to improve the sustainability of the return process and the potential effects of external factors. The external factors are identified using the PESTLE analysis, as introduced in section 6.1. In total, 5 scenarios are designed based on the PESTLE framework and MECE principle. MECE is particularly useful for designing unique scenarios to ensure they do not overlap, according to an expert of Metyis. MECE stands for Mutually Exclusive, Collectively Exhaustive [201]. The base case, as introduced in section 5.1, will be used to design the scenarios. Assumptions made for the base case are tested, and data will be adapted and analyzed with the developments identified for each scenario. Each scenario has a moderate and an extreme variant to investigate potential outcomes and effects, which are based on expert consultation, reports, and literature studies. An overview of the different scenarios is given in Figure 7.1, which are elaborated on in more detail in this section.

Scenario 1. Shifting customer behavior

This scenario entails the PESTLE analysis's Social (S) and Environmental (E) criteria. A visible market trend is customers' increased value and awareness of the environmental impact of their fashion consumption [131]. Changed customer behavior steers this scenario as customers focus more on sustainability practices. Customer behavior is a crucial component for lowering Greenhouse Gas (GHG) emissions in the fashion industry [194, 37, 12]. In this scenario, customers are both increasingly aware of the environmental impact of returns and want to improve their sustainability footprint. On the one hand, this leads to customers showing more conscious return behavior, researching better before buying a product, limiting opportunistic returning behavior, and lowering over-ordering due to environmental reasons. This can lead to lower product returns in general [194, 22]. If customers decide to return, they are more likely to choose the return alternative with a minor impact on the environment and reuse their package box, lowering the GHG emissions [191]. Accord-

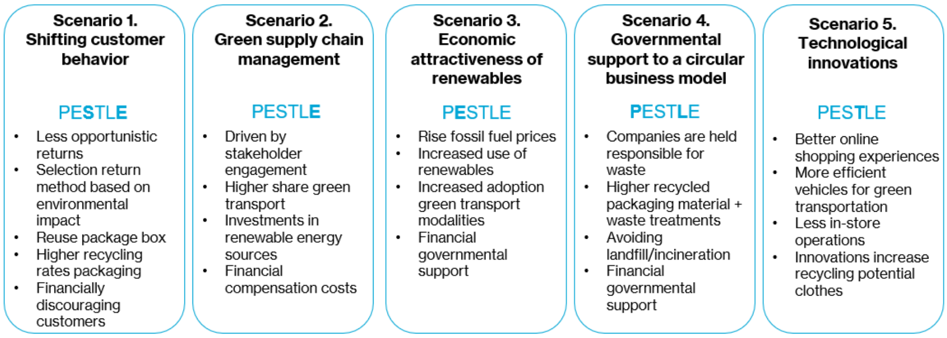

Figure 7.1: Overview of scenario design, source: (Author)

ing to an expert, retailers can recycle their packaging material better when the original packaging box is used. This can therefore lead to a higher recycling rate of packaging waste.

On the other hand, companies respond to this sustainable customer demand by improving transparency on the impact of the different return methods, which is lacking in the base case. Transparency may lead to lower returns as customers can make more conscious decisions [194, 22]. Further, companies invest in better product descriptions, online customer experiences, and assistance to lower purchase uncertainty in reaction to this conscious customer behavior. Fitting and uncertainty issues contribute significantly (i.e., 42%) to reasons for returns, indirectly affecting the environment negatively [95, 126]. Return reasons are also dependent on other factors; these are not incorporated in this scenario. Lastly, companies discourage opportunistic customer behavior by charging a return fee of 1 euro in the moderate variant and 2 euros in the extreme variant of this scenario. This fee is subtracted from the customer's refund after the returned product is received by the company. The company uses this fee to cover the warehouse's return handling and processing costs.

In the base case scenario, transparency on the environmental impact of product returns to customers is lacking, so customers are unaware of which return alternative would perform best in terms of environmental impact. Besides, there is still much potential to reduce the environmental impact due to improved conscious customer behavior [12]. The base case data shows that customers show a lot of opportunistic return behavior; sometimes, more than five products are returned in the same order. Therefore, the share of customers showing conscious return behavior is assumed to be very low in the base case scenario. Considering this, the moderate variant of this scenario assumes that 5% fewer products are returned due to more conscious customer behavior. The extreme variant assumes a more intense effort of customers and companies by incorporating more sustainability practices. The extreme circumstances take that 15% fewer products are returned due to more conscious customer behavior.

The moderate variant of this scenario supposes that 40% of the customers use the original packaging for returns, and the extreme presumes 60% of the packaging reusing. In the base case, it was assumed that the company recycled no packaging. Besides consultation with experts, the study of [191, 32], has shown that only 20% of the returned products are sent back in their original package. As larger amounts of the same packaging material are returned, companies are better able to recycle packaging, assuming 20% in the moderate variant and 40% in the extreme variant. These values are considered to be realistic, according to an industry expert.

The customers will consider the return method's environmental footprint for their selection, of which insights are lacking in the base case. The moderate variant assumes that 40% of the customers choose their return method based on ecological considerations, and the extreme scenario variant is 80%. The base case shows that the least preferred method from both environmental considerations is in-store returns, followed by the collection point (see subsection 5.3.4). This might differ depending on the data.

Scenario 2. Green supply chain management

Fashion companies focus more on integrating environmental practices into their supply chain [131]. This focus is driven by the strong emphasis of company shareholders on improving environmental performance. Therefore, this scenario's environmental (E) principle is a driving factor. Companies aim to improve the environmental impact of their whole supply chain, including transport, warehousing, and post-usage of products, so that environmental goals can be achieved and a company's brand image can be improved [209, 131]. A market trend that aligns with green supply chain management is greentailing. Greentailing, or eco-tailing, refers to a business strategy emphasizing socially responsible, environmentally friendly, and financially successful retailing across all commercial endeavors. Greentailing calls for retailers to increase the environmental performance of their supply chains and business operations while maintaining profitability [131, 137].

Transport providers are selected based on environmental performance. A shift from road transport towards more environmentally friendly fuels or modalities is visible for long-haul trips [108]. The short-haul trip, including the first and last-mile delivery, can be increasingly done with electric vehicles [186, 47, 151]. Additionally, governmental policies will help companies implement these renewable energies through financial support, making it broader available [61]. Companies will charge customers a fee for their returns to compensate for their investments.

Two variants of this scenario will be examined that incorporate green supply chain management; one moderate and one more extreme. A realistic shift for this scenario is consulted by an expert, considering the current base case situation. The moderate variant will ensure that companies' short-haul operations are 40% by electric vans, for 25% of the long-haul road transport, Liquid Natural Gas (LNG) is used instead of diesel [41], and that renewable energy sources supply 25% of the warehouse and buildings energy. Companies focus on changing the packaging type to improve their environmental impact by using recycled materials [191, 54]. In the moderate variant, 25% of the packaging material is made from recycled materials, which is 50% in this scenario's extreme variant. Corrugated carton boxes are, on average, half made of recycled materials [105] and are environmentally friendly alternatives to cardboard packaging [17]. 100% Low-density polyethylene (LDPE) is used for environmentally friendly plastic alternatives [94]. The more extreme variant of this scenario uses electric vehicles for transport for 80% of their short-haul operations, assumes a 50-50 share of diesel and LNG fuels for the long-haul transport, and supplies 50% of the warehouse and building energy by renewables. The transport costs for electric and LNG-fueled vehicles are derived from a study of [41] from 2020 that compared the price per kilometer for operating different fueled trucks. It is assumed that a company's investment in renewable energy for buildings leads to a 25% higher price in the moderate variant and 40% in the extreme due to economies of scale. A return fee of 2 euros and 4 euros is charged in the moderate and extreme variants, respectively, to compensate for these investments in renewable energy in the warehouse costs.

Scenario 3. Economic attractiveness of renewables

The fashion industry is primarily profit-driven, and economic costs are a primary factor in decision-making. In this scenario, economic developments are driving. A combination of inflation and rising prices due to shortages in fossil fuels has led to increased oil, coal, and natural gas prices in the market. Parallel to this development, governments aim to be less dependent on fossil fuels and invest more in renewable energy sources like solar, biomass, or wind power. Governments promote the adoption of renewable energy and offer, for example, a lower tax on renewable energy than fossil fuels [140]. Combining these factors will increase demand for renewable energy as it becomes a more cost-attractive alternative. As a result, Third Party Logistics Provider (3PL) can invest increasingly in greener vehicles in their fleet, leading to a broader offer of green modalities for a more competitive price. Besides, companies are starting to invest in renewables to power their stores and warehouses as it shows gains for both environmental and economic goals. Based on consultation with an industry expert in finance, developments in this scenario are formulated. A price increase of 5% is considered in the moderate variant of this scenario, together with an increase of 10% in renewables. The extreme variant assumes an overall increase of 10% of prices due to inflation and shortages, but renewables power 25% due to tax support on renewables. As fleets are increasingly becoming greener, the moderate variant assumes 10% of the kilometers are driven with electric vehicles, and in the extreme variant, 25%.

Scenario 4. Governmental support to a circular business model

In this scenario, governmental policies force companies to prioritize circularity in their business models. Circularity is a way to create value by lowering the GHG emissions created by waste processes in the operations [177]. An example of a governmental policy is the Extended Producer Regulation, where companies are held accountable for the waste generated by their products. There are different directions where fashion companies can include circularity in their operations.

Companies aim to lower harmful waste treatments and increase packaging recycling rates. An industry expert emphasizes the low quality of the packaging from returned products and, therefore, the lowered potential for recycling. Companies use stronger packaging materials to increase the recycling potential [131, 17]. This will lead to a recycling rate of 30% of the packaging material in the moderate variant and 60% in the extreme variant. Besides, companies focus on providing packaging made of biodegradable or recycled materials

[131]. The government has introduced European Union (EU)-Ecolabels to increase circularity and promote the environmental performance of products and consumption. An EU-Ecolabel can be granted if a product, service, or manufacturer meets specific scientifically developed and transparent criteria. These criteria are based on, for example, the created environmental impact, the energy efficiency, or the product's recyclability [57]. EU-Ecolabel for packaging requires a percentage of recycled material for at least 25% [80].

In this scenario, corrugated cartons are increasingly used to substitute cardboard, as these materials contain recycled content and are easier to recycle (50% in the moderate variant, 85% in the extreme) [54, 17]. The circularity of plastic bags can be improved when the material is made of 100% LDPE [94]. Governmental incentives in the form of financial subsidies increase the adoption of solar energy power and, thereby circularity of the warehouses and buildings. This leads to an adoption of 15% renewable energy for the warehouse and buildings in the moderate variant and 30% in the extreme variant of this scenario.

Recycling techniques are still under development, but companies donate a larger share of clothes that cannot be resold as new anymore to improve circularity. In the base case, donating clothes is not a common practice. An increased share of donated products will lead to fewer items being sent to landfills or incineration. Governmental policies will financially discourage landfill or disposal of clothes and increase charges by 20% per tonne textile in the moderate variant and 40% in the extreme variant.

The scenarios variants developed based on this increased demand for a circular business model are moderate and extreme, which are based on literature and consultation with several experts within multiple industries (finance, fashion, warehousing). In the moderate variant, 50% of the packaging material will be recycled, and 80% in the extreme variant. In the moderate scenario, 40% of the packaging is made of recycled materials; in the extreme scenario, this is 80%. The recycling techniques for clothing are still under development, so the moderate variant of this scenario will assume a reusing rate of 90% and the extreme variant of 95%. Under the reusing of clothes are also the clothes that will be donated. The share of donated items is nearly zero in the base case situation. The share of items sent to landfill and incineration is reduced to 5% each, respectively, in the moderate variant and 2.5% in the extreme. It is assumed that there is much financial and governmental support to increase circularity, so the investments made in the moderate variant lead to a price increase of 5%. In the extreme variant, this will be 7.5%.

Scenario 5. Technological innovations

Digitalization is a market trend that continues to grow and drives this scenario together with technological innovations (T) [25]. In a digital landscape, customers increasingly shop online and do not often use in-store alternatives, leading to higher e-commerce volumes. Companies adopt more innovative technologies in their business models and their operations. Specific technologies aim to improve the digital experience and presentation of products to customers and lower uncertainty issues when purchasing online [115, 117]. This will lead to a higher likelihood of ordering the correct product directly, reducing the need to return items for these reasons. Further, technologies will help optimize logistics and transport processes, reducing travel time and distances and adopting more innovative and efficient transport [86]. Additional development of electric and hybrid vehicles will increase the potential for adopting green transport on long-haul trips. Governments support shifting towards more renewable energies by providing adjusted infrastructure and financial incentives. Additionally, technological innovations make it possible to separate the waste streams and recycle more products. Developing mechanical and chemical sorting techniques will recover value from the end of a product's life [131, 111, 52]. In the current situation, it is assumed that no products are recycled, partly because of the low recycling rates and the uncertainty on the emissions- and cost of the recycling technologies. This scenario explores the recycling alternative with mechanical-based closed-loop recycling, which is based on fiber recycling [52]. From expert consultation, it was found that this alternative is the least cost-intensive and is likelier to be used.

Two variants of this scenario are developed. The first is the moderate variant, where the number of returns handled in-store is reduced by 50% compared to the base case. In this scenario, no consideration is given to the best environmental method based on the choice of the return method. The original in-store returns are randomly redistributed to home pick-up or collection point returns. The extreme variant of this scenario reduces in-store returns by 80% compared to the base case scenario. The transport innovations make transport more efficient, leading to an overall reduction of 5% emissions in the moderate variant of this scenario and 10% in the extreme variant. Misfit and sizing issues are the main reasons a product is returned (i.e., almost 50 percent according to [126]). Even with better-fitting technologies, the probability of returning due to these factors will still not equal zero. In the moderate variant, the total number of products returned is lowered by 10%. The extreme variant assumes that much uncertainty is taken away, and customers are likely to purchase the correct product directly, reducing the number of product returns by 20%. In the base case, recycling is not considered an alternative for waste disposal. Adopting recycling technologies will increase the share of recycled products to 5% in the moderate scenario and 15% in the extreme scenario. Further adoption of recycling technologies also requires a fundamental change in the materials of products, which is not assumed to be a feasible scenario for this research. 80% of the returned items are resold through reuse; the remaining share is equally divided by landfill and incineration.

7.2. Scenario testing

In this section, the designed benchmark and scenarios are measured, analyzed, and evaluated on the environmental and economic performance. The same phases are followed as in section 5.3 for the design of the CI.

7.2.1. Phase 1. Selection of the indicators

For each variable in the theoretical framework, the data is measured for the variants of the scenarios. This is presented in Table 7.1. Lower values are better for each indicator, and higher are less preferred. The best- and worst values over all the alternatives are highlighted in green and red, respectively, in the table.

Here: V_1: packaging emissions, V_2: transport emissions, V_3: warehouse and equipment emissions, V_4: product recovery emissions, V_5: brick-and-mortar emissions, V_6: transport costs, V_7: warehouse and equipment costs, V_8: labor costs, V_9: recovery costs, V_{10}: brick-and-mortar costs. An overview of the scenarios and their moderate and extreme variants is given in Figure 7.1.

Table 7.1: Raw indicator values for each scenario, source: (Author)

	V_1 [kgCO2e/ returned product]	V_2 [kgCO2e/ returned product]	V_3 [kgCO2e/ returned product]	V_4 [kgCO2e/ returned product]	V_5 [kgCO2e/ returned product]	V_6 [euro/ returned product]	V_7 [euro/ returned product]	V_8 [euro/ returned product]	V_9 [euro/ returned product]	V_{10} [euro/ returned product]
Benchmark	0.016	**14.498**	0.743	**0.007**	0.484	0.230	12.379	5.096	0.523	**1.903**
Base case overall performance	0.075	32.217	1.092	**0.012**	0.712	0.230	12.379	5.096	0.523	**1.903**
Scenario 1. Moderate	0.067	32.355	1.083	0.011	**1.083**	0.229	11.280	5.089	0.489	1.919
Scenario 1. Extreme	0.050	31.509	1.079	0.010	0.719	**0.227**	**10.226**	**5.085**	0.501	1.921
Scenario 2. Moderate	0.063	30.653	0.840	0.011	0.534	0.268	**14.069**	5.101	0.517	2.473
Scenario 2. Extreme	0.046	29.089	**0.587**	0.011	**0.356**	**0.307**	13.298	5.096	**0.485**	**2.664**
Scenario 3. Moderate	0.077	30.237	0.996	0.011	0.641	0.255	12.998	5.356	0.549	1.998
Scenario 3. Extreme	0.074	27.269	0.840	0.011	0.534	0.289	13.617	**5.606**	0.526	2.093
Scenario 4. Moderate	0.028	32.217	0.945	0.010	0.609	0.230	13.062	5.101	0.575	2.008
Scenario 4. Extreme	**0.016**	32.217	0.793	0.010	0.501	0.230	13.371	5.101	**0.615**	2.056
Scenario 5. Moderate	0.076	**32.468**	**1.117**	0.010	0.713	0.233	12.659	5.116	0.518	1.904
Scenario 5. Extreme	**0.078**	29.097	1.081	0.009	0.719	0.231	12.256	5.087	0.487	1.920

7.2.2. Phase 2. Normalization of the indicators

Next, the raw values are normalized using rescaling. The formulation of Equation 4.1 is adopted, as instead of return methods, the different scenarios are used as alternatives. Table 7.2 shows that the values of all variables are rescaled between 1 and 2. Here, a 2 represents the best value in terms of performance and a 1 the lowest. This transforms the variables' values to a standardized scale, making them comparable independent of their unit of measurement.

Here, V_1: packaging emissions, V_2: transport emissions, V_3: warehouse and equipment emissions, V_4: product recovery emissions, V_5: brick-and-mortar emissions, V_6: transport costs, V_7: warehouse and equipment costs, V_8: labor costs, V_9: recovery costs, V_{10}: brick-and-mortar costs. An overview of the scenarios and their moderate and extreme variants is given in Figure 7.1.

7.2.3. Phase 3. Weighting of the indicators

The variables are weighted using the weights obtained in the previous chapter in Table 5.5. For the benchmark, Analytical Hierarchy Process (AHP) weighting is adopted with Equal Weights (EW) (see section 6.2).

7.2.4. Phase 4. Aggregation of the indicators

Next, the CI scores are obtained by aggregation with multiplication, presented in Table 7.3. The aggregated values of the CI should be interpreted as follows: the highest score represents the best performance and the lowest is the worst. The results show that the benchmark, defining the target performance, scores best compared to all alternatives in terms of performance. Looking at the scenarios, the extreme variant of scenario

Table 7.2: Rescaled indicator values for each scenario, source: (Author)

	V_1	V_2	V_3	V_4	V_5	V_6	V_7	V_8	V_9	V_{10}
Benchmark	1.994	2.000	1.706	2.000	1.824	1.963	1.440	1.979	1.706	2.000
Base case overall performance	1.044	1.014	1.047	1.000	1.510	1.963	1.440	1.979	1.706	2.000
Scenario 1. Moderate	1.172	1.006	1.063	1.240	1.000	1.973	1.726	1.993	1.929	1.979
Scenario 1. Extreme	1.449	1.053	1.072	1.408	1.501	2.000	2.000	2.000	1.882	1.976
Scenario 2. Moderate	1.231	1.101	1.523	1.241	1.755	1.484	1.000	1.970	1.756	1.250
Scenario 2. Extreme	1.508	1.188	2.000	1.278	2.000	1.000	1.200	1.979	2.000	1.000
Scenario 3. Moderate	1.014	1.124	1.228	1.213	1.608	1.645	1.279	1.480	1.510	1.875
Scenario 3. Extreme	1.060	1.289	1.523	1.212	1.755	1.221	1.117	1.000	1.687	1.750
Scenario 4. Moderate	1.801	1.014	1.323	1.415	1.653	1.963	1.262	1.970	1.309	1.861
Scenario 4. Extreme	2.000	1.014	1.611	1.477	1.800	1.963	1.182	1.970	1.000	1.799
Scenario 5. Moderate	1.021	1.000	1.000	1.379	1.509	1.922	1.367	1.941	1.745	1.998
Scenario 5. Extreme	1.000	1.188	1.067	1.510	1.501	1.948	1.472	1.996	1.987	1.978

1, shifted customer behavior, comes closest to this benchmark performance with a CI score of 1.589. The extreme variant of the economic competitiveness of renewables scores the lowest, indicating the worst relative performance score, and is marked red.

Table 7.3: Aggregated CI scores, source: (Author)

	CI score
Benchmark	1.852
Base case	1.399
Scenario 1. Moderate shifting customer behavior	1.447
Scenario 1. Extreme shifting customer behavior	**1.589**
Scenario 2. Moderate green supply chain management	1.322
Scenario 2. Extreme green supply chain management	1.388
Scenario 3. Moderate economic attractiveness of renewables	1.352
Scenario 3. Extreme economic attractiveness of renewables	**1.294**
Scenario 4. Moderate governmental support to a circular business model	1.437
Scenario 4. Extreme governmental support to a circular business model	1.439
Scenario 5. Moderate technological innovations	1.395
Scenario 5. Extreme technological innovations	1.491

7.2.5. Phase 5. Post-analysis evaluation of the CI

The post-analysis evaluation provides an understanding of the robustness and reliability of the constructed CI. Several uncertainty triggers were identified during the construction of the model (X_1 weighting method, X_2 aggregation method, X_3 input data), see subsection 4.3.5. Insight must be obtained if- and to what extent different construction methods- or data would lead to different final values of the CI. First, the uncertainty sources X_1 and X_2 are analyzed, and their impact is discussed. Second, a statistical test is used to inspect the correlation of the uncertainty triggers. The uncertainty source X_3, changes in input data, is inspected with a Sensitivity Analysis (SA) by increasing and decreasing the values by 25%. The Pearson correlation coefficient is used to determine the statistical relation of this effect [147].

Uncertainty trigger X_1. Weights

The weights are rescaled to examine the impact of the first uncertainty trigger X_1. Three new experts are requested to assign weights from the perspective of a CEO, and this effect is analyzed on the final value of the CI. The pairwise-comparison matrix is constructed, resulting in the weights presented in Table 7.4. These weights are statistically checked to ensure sufficient consistency (Consistency Ratio (CR) < 0.10) [142]. The pairwise comparison matrix A can be found in section H.1.

With V_1: packaging emissions, V_2: transport emissions, V_3: warehouse and equipment emissions, V_4: product recovery emissions, V_5: brick-and-mortar emissions, V_6: transport costs, V_7: warehouse and equipment costs, V_8: labor costs, V_9: recovery costs, V_{10}: brick-and-mortar costs.

Table 7.4: Rescaled weights with AHP, source: (Author)

	Weight
V_1	0.031
V_2	0.167
V_3	0.054
V_4	0.069
V_5	0.032
V_6	0.231
V_7	0.128
V_8	0.118
V_9	0.106
V_{10}	0.082

Next, the normalized data from Table 7.2 was weighted using the rescaled weights and aggregated using multiplication. The scores of the CI are shown in Table 7.5. The scores should be interpreted as in Table 7.3, where higher scores correspond to better performance and lower scores to a less desired performance. As can be seen, the extreme variant of scenario 1 performs best, and the extreme variant of scenario three the worst.

Table 7.5: Aggregated CI scores obtained after rescaling weights, source: (Author)

	CI score
Benchmark	1.852
Base case	1.497
Scenario 1. Moderate shifting customer behavior	1.562
Scenario 1. Extreme shifting customer behavior	**1.652**
Scenario 2. Moderate green supply chain management	1.377
Scenario 2. Extreme green supply chain management	1.343
Scenario 3. Moderate economic attractiveness of renewables	1.403
Scenario 3. Extreme economic attractiveness of renewables	**1.292**
Scenario 4. Moderate governmental support to a circular business model	1.505
Scenario 4. Extreme governmental support to a circular business model	1.475
Scenario 5. Moderate technological innovations	1.506
Scenario 5. Extreme technological innovations	1.609

The values obtained with the rescaled weights are compared to the original values of Table 7.3. This is visualized in Figure 7.2, where the blue values indicate the original values of the CI and the green values the CI scores obtained by rescaling the weights. The height of each column represents the score of the CI, where a higher value represents better performance. The benchmark value remains unchanged; in both cases, EW is used. Both cases show that the same scenario variants perform best- and worst (S1E and S3E, respectively). Further, the overall performance scores increase after using the rescaled weights observed compared to the original weights. With the benchmark value remaining the same, all scenarios have a smaller performance gap by the benchmark. An explanation for this increase is that the rescaled weights of Table 7.4 indicate higher importance of the decision makers to economic indicators relative to the environmental indicators. This means that the economic performance will be slightly more influential in the overall performance. It is expected that scenarios that perform relatively better on the economic indicators than the environmental indicators show the highest increase relative to the original weights in overall performance. This hypothesis is confirmed when looking at the raw data values of Table 7.1 and comparing these with the outcomes in Figure 7.2.

Further, it is essential to see if the ranking of the scenarios has been changed to see the effect of rescaling. Most ranks have remained equal. However, S4M and S5M have switched positions; looking at the raw data, it is discovered that S5M performs a little better on the economic indicators, which are assigned higher weights now than SM4. Also, S2E has lowered by two positions ending at the second last, and S3M and S2M are increased by 1. This is a result of the relative importance of the decision-maker to the different indicators. As seen in Table 7.1, S2E performs relatively worse on the economic dimensions. As the economic indicators are perceived as more important than the environmental indicators after rescaling, it is a logical consequence

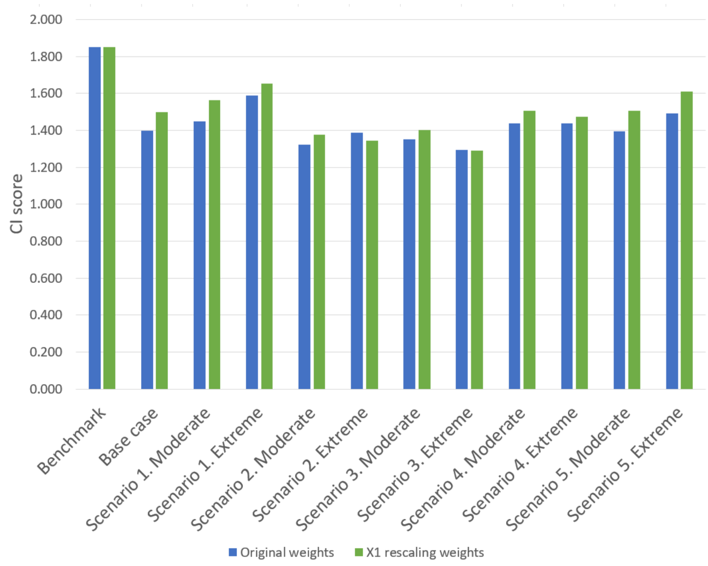

Figure 7.2: CI scores obtained with original and rescaled weights, source: (Author)

that this variant performs worse compared to the previously assigned weights. The results show thus no surprises.

Uncertainty trigger X_2. Aggregation method

The second uncertainty trigger is the aggregation method X_2, which is analyzed using the additive method (see Equation 4.9). This aggregation method is applied to the normalized data presented in Table 7.2 and weighted using AHP with the original weights from Table 5.5. For the benchmark, EW is used. The scores of the CI are shown in Table 7.6. Better performance is represented by higher values for the CI score and vice versa. The same variants score best- and worst compared to the initial results shown in Table 7.3.

Table 7.6: Aggregated CI scores using additive aggregation, source: (Author)

	CI score
Benchmark	1.861
Base case	1.442
Scenario 1. Moderate shifting customer behavior	1.500
Scenario 1. Extreme shifting customer behavior	**1.634**
Scenario 2. Moderate green supply chain management	1.340
Scenario 2. Extreme green supply chain management	1.409
Scenario 3. Moderate economic attractiveness of renewables	1.364
Scenario 3. Extreme economic attractiveness of renewables	**1.304**
Scenario 4. Moderate governmental support to a circular business model	1.469
Scenario 4. Extreme governmental support to a circular business model	1.485
Scenario 5. Moderate technological innovations	1.433
Scenario 5. Extreme technological innovations	1.522

As seen in Figure 7.3, the results after linear additive aggregation show a little increase in all the final scores of the CI compared to the original aggregation method, which was multiplication. As all scenarios are increased slightly, the ranking of all scenarios remains unchanged. However, the performance gaps with the benchmark for each scenario have improved slightly as the increase in CI score with the additive aggregation method is lower compared to the scenarios. This is the result of EW applied to the benchmark.

Testing the correlation of the uncertainty triggers X_1 and X_2

The correlation between the methods is investigated with Equation 4.11, where r ranges from -1 to 1, and values between 0.5 and 1 represent a strong and positive relationship [20]. So, from Table 7.7, it can be concluded that both uncertainty triggers X_1 and X_2 positively correlate with the original method of the CI, which

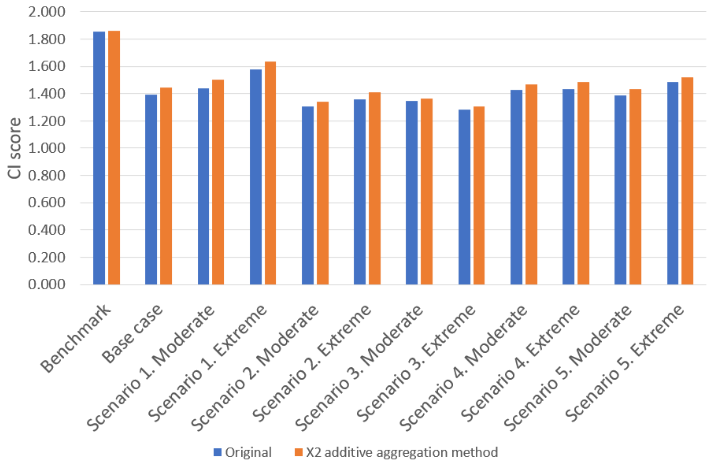

Figure 7.3: Overview of difference between the CI scores using GME and additive aggregation method, source: (Author)

has also proven significant at 0.05 and 0.01 levels. Thus, the null hypothesis H_0, stating that no correlation exists between the chosen and alternative construction methods, can be rejected at both levels for both uncertainty triggers [20, 203, 99]. So, the different construction techniques produce similar results.

Table 7.7: Outcomes correlation coefficient for uncertainty trigger X_1 and X_2, source: (Author)

	Correlation coefficient r	**t-statistics**	**Significant**
X_1. Alternative weighting	0.941**	0.101	yes
X_2. Aggregation method	0.994**	0.034	yes

* alpha < 0.05 (2-tailed)

** alpha < 0.01 (2-tailed)

Uncertainty trigger X_3. Input data

The third source of uncertainty examined is the input data X_3. Following from section 5.2, several data points are worth investigating based on the assumptions made in the base case and scenarios. The following uncertainty sources are selected based on the assumptions made and their expected effect on the model's output: equipment cost, transport costs of the electric distribution van, emission value for the warehouse, landfill costs, and incineration cost. The contribution of the uncertainty of the data values on the final value of the CI is examined by performing a SA [134]. Each input data value increases and decreases by 25%, while the rest remains unchanged. In Appendix H.2, the results on the scores of the CI are presented for each scenario together with the data after changing the variable.

The effect and contribution of the input data on the final CI is analyzed with the correlation coefficient. The results are presented in Table 7.8. From these outcomes, it can be concluded that there is a strong positive and significant relationship. All investigated inputs have an r close to 1, and p-values statistically significant at 0.05 and 0.01 levels. This indicates limited sensitivity to changes in the examined input data between the pairs of values, and H_0 can be rejected at 0.01 and 0.05 [20, 99].

7.3. Conclusion performance measurement scenario testing

This section evaluates the performance of the different scenario designs, which were presented in Table 7.3. The performance gap M will be determined to understand better the actual performance of the scenarios relative to the target performance. The performance gaps are calculated by Equation 3.3, using the data from Table 7.3. The performance gap represents the difference in performance between a scenario's actual and target values, which is the benchmark. The best performance is achieved when the values of all indicators are minimized, so a lower value for the performance gap M means a better performance score [49]. The results of the performance gaps with the benchmark are visualized in Figure 7.4. In Appendix G, the relative performance and the performance gap can be found for each scenario.

The base case and the scenarios are plotted on the horizontal axis in Figure 7.4. The height of the column

Table 7.8: Outcomes correlation coefficient for uncertainty trigger X_3, source: (Author)

	Correlation coefficient r	t-statistic	Significant
Equipment cost (+25%)	0.992**	0.039	yes
Equipment cost (-25%)	0.981**	0.059	yes
Electric van transport cost (+25%)	0.988**	0.049	yes
Electric van transport cost (-25%)	0.976**	0.067	yes
Warehouse emission value (+25%)	0.991**	0.044	yes
Warehouse emission value (-25%)	0.993**	0.036	yes
Incineration cost (+25%)	0.961**	0.030	yes
Incineration cost (-25%)	0.992**	0.039	yes
Landfill cost (+25%)	0.990**	0.042	yes
Landfill cost (-25%)	0.992**	0.040	yes

* alpha < 0.05 (2-tailed)
** alpha < 0.05 (2-tailed)

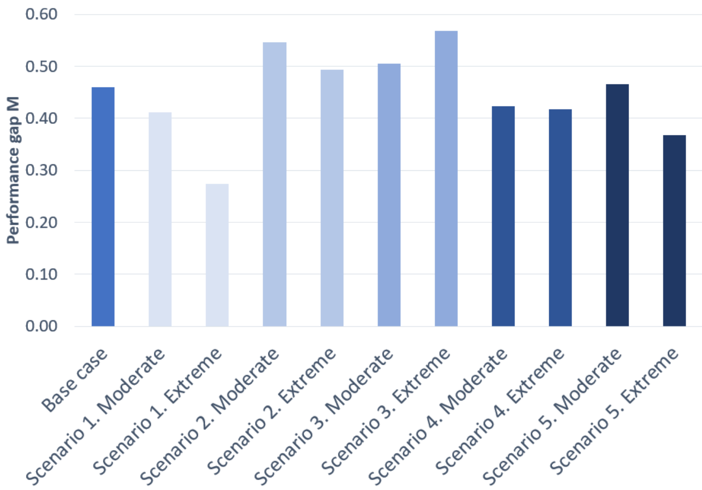

Figure 7.4: Performance gaps scenarios relative to the benchmark, source: (Author)

represents the performance gap relative to the benchmark. The largest performance gap is found in the extreme variant of scenario 3; the economic attractiveness of renewables. The extreme variant of scenario 1 has the smallest performance gap with the benchmark relative to the other scenarios, indicating better performance. In Appendix I, radar charts are presented for each scenario with the benchmark and base case. This gives an in-depth understanding of the developments in the scenarios. The performance of the base case with the benchmark was already analyzed in section 6.4, and the radar chart is presented in Figure I.1.

Both variants of scenario 1 have a smaller performance gap than the base case with the benchmark, meaning better performance. Although recycling is more costly than landfill or incineration alternatives for packaging, the overall performance is improved in both variants of this scenario compared to the base case. The higher costs of packaging are compensated for by better environmental performance and the usage of financial incentives by companies to discourage returns, which also helps lower the return cost for a company. The return fee is used to lower the warehouse and equipment cost, leading to a relatively good performance on this indicator in both cases of this scenario, as seen in Figure I.2. The extreme variant of this scenario shows a relatively sizeable improved performance compared to the moderate variant and the base case, partly due to the higher return fee to discourage customers from returning and better environmental performance. Also, customers consciously choose their return method based on environmental considerations, lowering the number of returns in-store. This leads to an improvement in the brick-and-mortar emissions and transport emissions accordingly in both variants of this scenario compared to the base case.

Both variants of scenario 2 have worse performance than the base case relative to the benchmark. Both variants show high costs, as seen in Table 7.1. So, the increased environmental improvement efforts in both scenarios do not outweigh the costs, leading to a bigger performance gap with the benchmark. Figure I.3 shows that modality shift, more environmentally friendly packaging material, and investing in renewable energy sources for buildings lead to better environmental performances and, in the extreme variant, may even outperform the benchmark. Although the company charges a return fee in both variants, no governmental financial support is given to lower the costs. Therefore, these economic costs are not compensated by environmental gains. In the extreme variant, the efforts are more compatible with the costs made, improving the overall performance compared to the moderate variant of this scenario. However, the overall performance is not improved compared to the base case, as the costs in the extreme variant are highest for both transport- and brick-and-mortar stores, which were as expected as large investments were made.

Both variants of scenario 3 perform worse compared to the base case relative to the benchmark due to the higher prices of inflation and fossil fuel. Figure I.4 shows that the performance is better relative to the base case only for the transportation, warehouse and equipment, and brick-and-mortar store emissions. Although renewable energies and green transportation modes are increasingly attractive, the costs are still too high. The extreme scenario, where more environmental improvements are made but a higher price increase is assumed, shows even worse performance compared to the moderate variant of this scenario. Mainly, the labor cost is high in this scenario's extreme variant, resulting in a price increase of 10%.

The performance gaps of both moderate and extreme variants of scenario 4 are smaller compared to the gap of the base case with the target performance, meaning that improvements are made. This results from a higher packaging recycling rate, more environmentally packaging material, a higher reuse rate of the clothes, more products donated, increased adoption of renewable energy sources, and fewer products disposed of or sent to landfills (see Figure I.5). Yet, adopting these efforts leads to high recovery costs (V_9). It can be seen from the extreme variant of this scenario that the efforts focusing on adopting renewable energy sources in buildings (V_3 and V_5) come close to the benchmark values. This scenario illustrates that the government's financial support has ensured that the overall price increase due to company investments does not outweigh the environmental improvements. This makes both variants of this scenario function better in terms of overall performance than the base case. No improvements are made for the transport costs and emissions in this scenario.

The moderate variant of scenario five, technological innovations, shows no improvements compared to the base case relative to the benchmark. The more detailed radar chart in Figure I.6 shows that the moderate variant of this scenario outperforms the base case on product disposal emissions. However, the higher recycling and transport costs lead to an overall decrease in the performance of this variant relative to the base case. In the extreme variant, improvements are visible due to more efficient transport, fewer in-store returns, higher clothing recycling rates, and lower costs due to economies of scale. Under these conditions, advancements are observable compared to the base case, and the performance gap with the benchmark is tightened. One outlier in the extreme variant compared to the moderate variant of this scenario is the transportation improvements, leading to relatively large improvements in transport emissions in the extreme variant.

7.4. Validation

Validation examines the question *'Is the model right?'*. This question relates to the defined objectives, requirements, and purpose. Validation consists of conceptual and operational validation [143]. This research will only validate the model by conceptual validation, as no real-life observed results are available to compare the model's output. Conceptual validation investigates the correctness of the assumptions made in the model and whether the model performs plausible results [104]. It is determined whether its behavior aligns with the expectations by testing the effect of different scenarios. Scenarios were designed based on the verification framework of PESTLE and expert consultation, which improves the reliability of the scenarios with real-life developments. After testing the scenarios with the model and conducting a performance analysis, it was concluded that the scenarios generated plausible results. This proves the correctness and reliability of the model and creates a better understanding of the model's behavior and how it performs. The model can provide desired outputs, serve its purposes, and create valuable insights.

The model is successfully validated by inspecting the plausibility of the behavior of the scenario outputs.

7.5. Main findings chapter 7

First, the sub-question *How can companies use the constructed CI in practice?* is answered. In the previous chapter, it was already found that a company can measure and compare the performance of its different return methods relative to a verified benchmark. This creates the knowledge for companies to encourage customers to make more environmentally friendly choices for returns based on their current performance. It also creates an understanding of how their current performance scores on the environmental targets the EU set on their performances. In this chapter, the verified benchmark was used to give companies insight and understanding into potential improvement areas of their returns. The impact of external factors and the effects of adopting strategies to improve sustainability on a company's performance was analyzed using scenarios based on PESTLE, literature, reports, and expert consultation. The outcomes were translated to performance gaps, identifying a company's performance relative to their benchmark performance. The results showed companies insight into the effects of implementing different strategies or actions and external factors on their performance. This helps identify potential areas of improvement and risk and how they can reach the targets set by the European Commission (EC), demonstrating how companies can use this CI and the insights created by its usage.

The model is conceptually validated by investigating the model's behavior by scenario analysis. Multiple scenarios were developed based on the PESTLE framework, which was tested with the model, and their effect on the model's output was evaluated. The model is successfully validated by inspecting the plausibility of the model's behavior and the scenario outputs. This proves the correctness and reliability of the model and contributes to a better understanding of the model's performance, answering the question *How can the constructed CI be validated?*

8
Conclusion and Discussion

This research will conclude with the findings of this research. Each research chapter has ended by answering one of the sub-research questions; these insights will be combined to formulate an answer to the Main Research Question (MRQ). Next, this research's scientific and practical contributions are discussed, together with the limitations. Finally, recommendations for future research are made.

8.1. Main findings

To achieve the goals the European Union (EU) set to combat climate change and comply with increased market pressure, the fashion industry must change and lower its Greenhouse Gas (GHG) emissions [72, 182]. The ongoing rise of product returns has become an increased problem for this industry as it exacerbates its GHG footprint when it should be lowered. This leads to undesirable consequences for companies and society, and improvement of returns is necessary [63, 36, 50]. The problem of returns should be tackled by both lowering the environmental impact of the process of unavoidable returns and the number of returns in general [36, 63], leading to environmental gains for society and cost savings for a company [194, 63]. Although transparency and understanding of the impact of returns on the performance of a company are needed to effectuate change [182], there is a knowledge gap as the environmental impact of product returns, and how this impact differs per return method is poorly understood, and accurate methods to assess this impact lacks [183, 36]. Therefore, this study has assessed the impact of product returns on the performance of fashion companies and created an understanding of this to improve the environmental footprint. Besides the scientific relevance of developing a method for assessing returns from an environmental viewpoint, the fashion industry is primarily profit-driven, and this study considers both dimensions relevant to ensure effective and realistic decision-making. Therefore, the economic impact of product returns on a company's performance is also measured, creating a company performance measurement with multiple dimensions. The outcome is a Composite Indicator (CI) for companies to measure, analyze, and evaluate their performance and see how different return methods or improvement strategies affect this. A new benchmark is designed based on GHG reduction targets of the European Commission (EC) for 2030 which is developed and integrated into this CI to help companies improve sustainability. The MRQ of this study is:

"How can a Composite Indicator be constructed to provide insight into the environmental and economic performance of product returns for companies within the fashion industry and help improve their sustainability?"

This CI was constructed in five steps, where the performance is measured using indicators. First, it was determined which environmental and economic indicators needed to be included in this CI to measure the impact of product returns on a company's performance and how these could be quantified. This was done using a literature study and interviews with experts, and the findings were combined into a theoretical framework. Second, the indicators were normalized by rescaling. Third, the Analytical Hierarchy Process (AHP) technique was applied to weigh each indicator. The indicators were aggregated into one measure in the fourth step using the multiplication technique, followed by evaluation of the robustness of the CI using a Uncertainty Analysis (UA) and a Sensitivity Analysis (SA). Lastly, a benchmark was designed using literature, reports, and expert consultation and developed and integrated into the constructed CI, where AHP weighting was replaced by Equal Weights (EW).

In more detail, five sub-questions were defined that were answered throughout the research to pose an answer to the MRQ. The main findings of these questions are elaborated on below.

SQ1. What does the fashion industry's product return flow look like?
The returns process consists of a return request, collection, handling, processing at the warehouse, and product recovery and disposal. The return process starts when the customer requests a return and selects a method to process this, which can be: by brick-and-mortar store return, drop-off at a collection point, or by home pick-up. The availability of the return methods for a customer depends on whether the retailer offers this service. The customer must re-pack the product for safe transport if home pick-up or collection points are chosen. Next, the product is collected and transported from the customer to the final recovery destination, either the warehouse or the brick-and-mortar store. How this transport is arranged depends on the return method chosen. Products with the brick-and-mortar store as the final destination are restocked and resold. If the product is sent to the warehouse, it will be received, handled, inspected, and temporarily stored until a decision is made on how to recover it. The recovery choice determines if the product gets resold, recycled, repaired, remanufactured, or disposed to landfills or incineration [45]. After the recovery activity is performed, the process of returns is finished.

SQ2. How can the environmental impact of the various logistic activities involved in product returns be assessed?
The following elements were essential for assessing the environmental impact of product returns: packaging material, packaging waste treatment, transportation, warehousing, storage, equipment usage, product recovery, and brick-and-mortar activities. An activity-specific Emisison factor (EF) was used to measure the GHG emissions of each activity, following the guidelines of the GHG Protocol. The choice of a return method is relevant to the environmental impact of packaging, transportation, and brick-and-mortar activities.

SQ3. How can the economic impact of the various logistic activities involved in product returns be assessed?
According to several experts, activity-based costing is a commonly used method to assess the return costs for a company. The following costs were considered to create a complete overview of the process of returns from an economic perspective: transport costs, warehouse space utilization costs, equipment costs, labor costs, product recovery and disposal costs, product storage costs, in-store space utilization costs, and in-store product processing costs. Measurement of these costs was done on an annual basis and specified per return.

SQ4. How can a CI be created to assess product returns' environmental and economic impact?
The structure of a CI involved five steps and was done according to the guidelines proposed by [134]. First, ten indicators to measure were selected using the insights created in SQ1, SQ2, and SQ3. This provided insight into the raw indicator values and the overall environmental and economic impact of a return method before aggregation. Second, the indicators were normalized by rescaling and weighted by AHP. AHP allows companies to make a trade-off between the importance of the indicators amongst each other but ensures consistency by using statistical methods to determine the weights [134]. Next, the indicators were aggregated using multiplication, a commonly used technique that allows straightforward interpretation and partial compensability of the indicators [120, 133]. The same construction techniques were used to design the benchmark in the CI, but the weights were assigned using EW to improve the transparency of the benchmark. Lastly, evaluation of the CI was done by performing a UA and SA that verified and validated the CI using data from a fashion retailer. This confirmed the robustness of the model, and evaluation has proven that the CI can meet its objectives and requirements.

Q5. What is the most preferred return method for a company considering its environmental and economic performance?
The environmental and economic impact of each return method in the base case were calculated in the first phase of the CI. Combining the environmental set of indicators shows that from the return methods, home pick-up creates the lowest GHG emissions per return, followed by collection point returns, and in-store returns score worst. The costs per return are highest for in-store returns, followed by collection point returns, and home pick-up has the lowest cost per returned item. The differences between the performances of the return methods are larger for the economic set of indicators. So, considering the environmental and economic

performances separately, home pick-up performs best on both dimensions and is preferred over the other return methods. This outcome aligns with the results from the aggregated CI scores, where home pick-up has the best overall performance, collection point in between, and in-store returns the worst.

8.2. Discussion

This section discusses the scientific and practical research contributions. Additionally, the limitations of this research are discussed to give a better understanding and interpretation of the results.

8.2.1. Scientific contributions

Multiple contributions were made in this study to scientific research. The first contribution was adding research to the scarce scientific literature on reverse logistics in the fashion industry, focusing on the effects and potential solutions for improving the environmental impact of customer product returns. The need to create this knowledge and increase transparency on the environmental impact of product returns was emphasized by [202, 23]. The second contribution was developing a measurement method for analyzing the GHG emissions of a return that include all relevant logistic activities and return methods. The few studies in this field were incomplete as these did not include all relevant logistic activities in this process, were limited to only analyzing carbon emissions, or did not consider the differences between the return methods [36, 118, 51]. The third contribution was developing a new CI that fashion companies can use to measure, evaluate, and improve the impact of product returns on their environmental and economic performance, which was lacking in research. Companies can thereby provide transparency on the impact of returns and can encourage more conscious return behavior [194, 23], which was a gap in the literature [22]. In addition, this research expanded the field of research on company performance measurement with CIs by assessing both environmental and economic dimensions [203]. The final contribution of this research was providing a new overview and measurement method where insight into the performance of different return methods was obtained and how they differ on their performance for a company. Although it was acknowledged that the impact of these return methods differs and improvements could be gained by choosing methods based on their performance [23, 22, 51], this insight was lacking in the literature.

8.2.2. Practical contributions

The practical contributions made with this research are formulated from a fashion company's and society's perspectives.

Perspective fashion companies

This research contributes to improving the ongoing problem for companies that may account for approximately 12% of their GHG emissions [9] and where they may lose yearly approximately 17% of 1 billion dollars in sales to [3, 135]. Contributions are made to improve companies' performances by, on the one hand, lowering the number of returns and, on the other hand, improving the current process for unavoidable returns.

Fashion companies can improve their performances by measuring the process of returns: lowering their environmental footprint- and costs. This study provides insight into the sources of GHG emissions and the costs of product returns, and how companies can measure them. Also, differences between the return methods and their performance are made explicit for companies. Companies can make well-informed decisions to improve the environmental impact of returns as they can define, measure, compare, and prioritize improvement efforts based on environmental impact while ensuring economic viability [182]. This relevance was proven by conducting a case study of a fashion retailer. It showed valuable insights into how its performance could be improved by avoiding or selecting a return method based on its impact and which trade-offs could be made between environmental and economic performance for implementing new strategies to improve the return impact.

Companies can mitigate returns by encouraging customers' conscious return behavior, leading to environmental and economic gains for a company [194, 23]. This study has provided a tool for companies to gain insights into the impact of returns and the different methods so that they can measure, analyze, and compare the performance between return methods. Awareness can be created about the impact of returns, and opportunistic return behavior can be limited, lowering returns. Also, with the increased transparency, companies can answer the increased customer pressure for more well-informed and conscious return choices [22]. Conscious return choices- and behavior improve company performance on both environmental and economic facets as less environmentally damaging return methods are chosen [23], and fewer products are expected to be returned [194]. This research showed that encouraging conscious behavior and thereby reducing the number of returns is a very effective way to improve the overall performance of a company.

This research has proven the added value for companies to compare their performances with a benchmark. Companies know how far they are in reaching the goals of the EC to combat climate change. The EC targets for 2030 to lower the GHG emissions were translated into indicator-specific goals in this study. This research has defined a verified benchmark representing these target values. Companies can compare their performance relative to this benchmark. With this, companies can see how far they reach these targets and how- and to what extent (potential) changes in their operations might lead to solutions to close this gap. Additionally, companies can use the results of this CI to respond to the prospected environmental reporting of the EC on the environmental impact of operations.

Societal perspective

This research contributes to halting climate change by focusing on one of the most environmentally polluting industries worldwide. Attention is given to the increased problem of product returns, which received too little attention previously. Although returns are not the largest share of emissions along the value chain, the problem of returns continuously grows and generates negative externalities for society [63, 36]. This research pays attention to this problem by providing insights into how returns can be mitigated and how the process of returns can be improved.

The role of fashion companies was already mentioned. Further, customers have an essential role in establishing change as well. Increased customer awareness on the impact of returns and limiting opportunistic return behavior is needed to achieve the potential savings of 12 million tonnes of GHG emissions when the return rates would decrease by 20% [12]. This research is dedicated to increasing knowledge on the impact of returns and contributes to creating awareness about the environmental costs of returns. Customers should also be held responsible for the negative externalities of these returns created, as their behavior drives high return rates. This is an essential contribution of this research, as besides the companies, customers also have to take responsibility and have an important role in lowering the environmental impact of product returns and creating a positive impact on society.

Next, a contribution is made as a transparent tool is provided, where customers and governments know which- and how the environmental impact of a product return is measured for a company's performance. The insights created give customers clear and transparent information about the GHG emissions of a return, where the complete return process and return activities are considered. For governments, this tool contributes as it can be used in their prospected mandatory environmental reporting sector-wide. Governments can use this transparent tool to evaluate, monitor, and track the progress of a company's performance and evaluate the efforts made by companies in achieving the EC goals to become net-zero. Companies' performances within the sector can be compared with each other as they are measured with the same measures, their progress can be evaluated, and governments can use this benchmark to set more concrete targets to combat climate change.

Further, governments are drivers to effectuate change in this industry and should have a more leading and supporting role in tackling the growing problem of returns. Currently, no specific government regulations target the return process of fashion companies, although this is a growing phenomenon in the industry that exacerbates the GHG emissions. A more leading and supporting role is desired. Regulations incentivizing companies to integrate sustainability practices in their returns are essential, as well as government financial support for companies to remain profitable.

8.2.3. Limitations

This section gives a discussion on the limitations of the research and the results to understand and interpret them better.

Research scope and approach

As reducing GHG is the top priority of the EC to combat climate change, this research is demarcated to only measuring the GHG emissions of the process of a return [67]. The relevant EC targets set for reducing GHG emissions are translated into a target benchmark in this research. As the assessment of this research is consistent with the unit of measurement of these targets, this tool is highly suitable for companies to measure their progress relative to these EC objectives. Yet, the environmental impact of product returns is broader than only the GHG emissions, as negative externalities like noise and water pollution are also created [106, 170, 72]. These effects are not considered in this assessment. A more comprehensive overview of the environmental impact of product returns can be made by including these factors, which is a limitation due to this study's scope.

Further, only the environmental impact created in the return process was considered in this study. However, companies increasingly use carbon offsetting alternatives, where financial compensations are paid to compensate for the emissions the buyer creates, lowering their emissions [82]. This is not considered in this research. If a company uses carbon offsetting while using this research's CI, it should be specified for which activity the offsetting is used, and double-counting should be avoided. It is essential to provide transparency on this to enhance the quality of the outcomes.

Research methodology, results, and data
This research aimed to create a CI to measure company performance in the process of product returns. Constructing a CI involves some level of subjectivity as choices must be made for the construction methods. To lower potential subjectivity, the choices were communicated, motivated, and made transparent in this research. In addition to this, the effect of these choices on the models' output was investigated by performing a combination of UA and SA. The results showed that the constructed CI is robust, as using a different construction method leads to similar results, increasing the reliability of the selection of construction methods. Special care was given to test the reliability of the weighting method. Although the consistency of the weights was verified using a statistical test, the expert group was within the recommended range of 3-7 experts, and a different group of experts was used for rescaling, it might be argued that the reliability of the weighting method still can be improved by increasing the number of experts to assign weights. Nevertheless, the choice of construction methods was successfully verified, lowering the risk of subjectivity.

The first objective of the CI was looking at whether the performance of an average return item with the different return methods for a company can be measured and how- and if these methods can be compared. The CI shows that home pick-up returns perform best based on the data set used of a fashion retailer, followed by collection point returns and the in-store scoring worst for this retailer. Considerable differences are seen in transport emissions- and costs, the warehouse- and equipment costs, and the warehouse- and equipment emissions between the methods. Identification of the underlying causes of these outliers shows plausible and logical results. For example, home pick-up performs much better on the average transport emissions per return due to the more efficient transport networks. However, home pick-up is more costly as longer distances are driven with relatively expensive distribution vans. In-store returns have lower transport costs as customers bring the product to the brick-and-mortar store but score worst on transport emissions as no consolidated shipments are used. From this in-depth analysis of the results of the return methods with this data set, it can be concluded that the first objective can be served with this CI. Nevertheless, it should be noted that the findings from the base case in this research cannot be directly generalized to other fashion retailers as they are highly company-specific. For example, transport emissions depend on the distance driven, which depends on the location of the warehouse, customers, distribution centers, return strategies, and modalities used. So, it can be that different return methods perform better than the findings from this research pose based on the data set used. This research is limited to the data set of only one fashion retailer, so to create more generalizable results, data sets from different companies should be measured, analyzed, and evaluated.

The second objective of this CI was to enable companies to identify areas of improvement, track progress, and compare their performance relative to targets. These objectives can be fulfilled with the CI developed in this research. A benchmark was constructed according to specific targets driven by Legal (L) and Policy (P) factors from the PESTLE framework, which serves as a verification tool. Companies can compare their actual performance with the target performance by measuring the performance gap. The magnitude of this gap expresses how far a company is in terms of performance in reaching the targets. Scenarios were designed using the PESTLE framework, literature, reports, and expert consultation, which showed the practical usage of the CI to identify improvement areas and economic risks on their performance. It was found that, based on this company's data set, the most considerable improvements in overall performance can be achieved when fewer products are returned due to more conscious behavior and, on the other hand, a higher recycling rate of packaging materials is achieved. Additionally, a return fee to discourage customers from returning items also leads to performance improvements relative to the base case, closing the gap with the benchmark. This is a crucial component to lower the costs of returns when no governmental support is given. The scenario analysis shows the importance of the financial support of governments for companies to ensure feasibility in company efforts to improve their environmental impact. Adopting less harmful waste treatments that enhance circularity shows improvements in environmental areas but are slightly higher in costs, affecting the overall performance. The gains achieved by technological innovations depend on the availability of technology and economies of scale that might help to lower costs, shrinking the performance gap with the benchmark. The insight gathered from evaluating the results of the CI can be used to make more informed decisions, prioritize improvement efforts, and design actions to improve sustainability while ensuring economic feasibility. These analyses validated the models' behavior and results, showing that the model can meet its objectives, requirements, and purpose.

When interpreting the results, emphasis should be given to the benchmark. The benchmark represents a company's shorter-term goals to comply with EU targets by 2030 in its net-zero journey for 2050. As companies can make trade-offs between environmental and economic indicators to measure their performance, EW is applied for the benchmark values in this CI. This ensures that the values of the benchmark are generalizable and transparent sector-wide. For the definition of the environmental indicators, the targets for 2030 are derived from EU targets and reports and stated in section 6.2. Companies need to reduce their emissions according to reduction percentages set by the EU. This is incorporated in this benchmark but has as a result that the raw values of the benchmark are company-specific. The reduction targets are translated into values for the benchmark using the data set of the base case for the specific base year. So, when a company uses this CI, it should define the benchmark values accordingly to its own data. Further, the target values are determined according to EU legislation, so this should be considered when a company outside the EU wants to use the benchmark targets. The set-up and structure of the benchmark can be used. Still, the target reductions should be defined accordingly to the policy and legal objectives and requirements that the company needs to obey. It is recommended to verify the target values with experts to ensure an accurate benchmark. As mentioned, defining any accurate target values for the economic indicators for 2030 is not possible. The economic indicator values are subject to uncertainty and external influences, so deriving numbers for these indicators for 2030 is not likely to be representative or accurate. Therefore, the base case values for the economic indicators are used in the benchmark. This is certainly a limitation of this research and should be considered when interpreting the results. By exploring the effect of different scenarios on a company's performance, the effect of the economic indicators was demonstrated. This analysis has shown that variance of the economic indicators can lead to large improvements in the overall performance of the CI, which needs to be considered for the CI interpretation.

According to expert consultation, the input data of this CI to measure the environmental and economic impact of the returns is well designed and suitable for companies. Companies should have all the inputs required by themselves to measure their performance. Data from the client retailer was obtained, analyzed, and prepared with a data expert from Metyis. Unreliable data points were removed to ensure consistency in the data set, and data from a whole year was used, so demand fluctuations were considered. However, the data set used in this research was not fully complete, partially due to confidential reasons, so some data was not shared. Assumptions needed to be made, and input data from secondary sources were used for supplementation. Special care was given to inspect the reliability and accuracy of the input data and the assumptions made. The input data and assumptions were validated by looking into the reliability of the data source, its year, and geographical dependency of the data, and experts checked assumptions with their industry knowledge. Additionally, the impact of some of these uncertainties in input data on the final value of the model was analyzed and evaluated using a SA. This statistical test revealed that the model's outcome is robust to changes in data, reflecting the resilience of the CI and increasing its reliability. However, the data's reliability would be improved when this is not obtained through secondary sources, all data originates from the same year, and fewer assumptions were made. Nonetheless, special care is given to this, and the reliability of the missing data and assumptions is increased through validation.

From the literature, several waste treatments were identified [45, 107, 5, 77]; however, expert consultation indicated that the treatments used are pretty limited for return operations by fashion companies in practice. Recycling is increasingly promoted to improve circularity, but in reality, the adoption of this technique is currently shallow due to technical and economic feasibility [52]. Additionally, assessing this impact requires a high level of detail, as the emissions created due to recycling largely depend on the type of clothing recycled, the technique chosen, and the efficiency of that technique [166]. As there is very little data available on this treatment in the literature, additional assumptions would need to be made that would negatively affect the quality and reliability of this research. Therefore, it was decided to exclude recycling as an alternative in the base case. For the scenario analysis, the impact of mechanical recycling is explored and included in one of the alternatives as optional waste treatment. The costs- and emissions are based on reports but are still highly embedded with uncertainty, which should be considered with interpreting the results. If a company uses recycling techniques, they can adopt this in this CI by including the economic cost of this treatment. The environmental impact should be determined as accurately as possible, where preferably the type of clothing item and its material is considered.

Another limitation of this research is that it assumes the activities of the Third Party Logistics Provider (3PL)s at the distribution centers activities of the 3PL to be neglectable. However, these activities may generate additional emissions, depending on the 3PL their performance, and should therefore be discussed. This research aimed to measure the environmental and economic impact of returns on the performance of fashion companies. Consultation with experts from the industry gave insight that fashion companies lack information and data on the GHG emissions of their 3PL at their transfer locations or distribution centers. Additionally, the specific activities at these distribution and sorting centers of the 3PLs are not within the control of fashion companies, making it difficult or even impossible for them to effectuate change here. So, assumptions are necessary to make. From reports published by the 3PLs, it follows that for PostNL, the 3PL transporting more than 90 percent of the returns in the base case, their buildings are entirely free of emissions and optimizing their operations [151]. However, for other providers, like UPS, insights are lacking. This lack of data makes it difficult to make reliable assumptions about the emissions generated by these activities on the product return level. Therefore, the decision to neglect these emissions in this research is twofold; first, the information provided by PostNL on their performances and the total share of this 3PL as a transport provider for the returns in the base case, second the lack of data on other 3PL. This assumption is further investigated by performing a SA for the warehouse emissions, which found that the results generated by the model in the base case were not sensitive to changes in this variable. However, this is still a limitation in this research, and further investigation into the activities and emissions generated at these distribution centers would improve the accuracy.

8.3. Recommendations

This section gives recommendations and outlines future research possibilities. Some of these recommendations come from the research findings and limitations; others are based on insights gained during the research, which require further investigation.

The main recommendation of this research is for companies to offer return methods to customers based on how they perform to improve the environmental impact. The findings of this research have shown that the impact of the return methods differs, considering both environmental and economic dimensions. Improvements can be achieved when companies avoid return methods that perform worse as an alternative to return a product.

Next, as a transparent tool is provided on which- and how the environmental impact of a company is measured, it is recommended for governments to use this tool in their environmental sustainability reporting for companies. Additionally, the integrated benchmark can be used by the government to compare the performances of companies sector-wide, measure their progress, and set further targets to combat climate change.

This study has created the information needed to provide transparency and inform customers but does not analyze how- and where companies in the purchasing- and return process can use this information the best to encourage customers' conscious return decisions- and behavior most effectively. Therefore, it is recommended to develop a dashboard or digital twin where insights are obtained where- and how customers can best be encouraged using the insights obtained from this study.

Further, it is recommended that companies mitigate the number of returns by adjusting the leniency of return policies. Lenient return policies of companies are causes for high return rates. The scenario analysis has shown that lowering the number of returns and charging customers a return fee significantly improves overall performance. However, companies are less willing to change these policies and make them less lenient as it is a tool to boost sales and attract customers and, therefore, impacts their profitability, they say [194, 175, 93, 101]. However, this research showed the potential to improve the company's performance by changing the return policies. The potential effect on customer sales was left unconsidered, forming the basis for the following possibilities for future research, which have both practical and scientific implications. First, the findings of this study should be incorporated to design new return policies, targeting lowering returns using financial discouragements based on the environmental impact created when returning a product. Research should be conducted into optimal financial discouragement while considering its effect on customer demand and a company's profitability. Also, exploring the efficiency of targeting specific product categories with their return policies is recommended, as some categories cause higher returns than others. The effect of the policies can be analyzed and tracked using the CI developed in this research. These insights may help companies adjust their return policies, contributing to lower returns and improved environmental impact.

Investigating the decision-making behind the choice of a company on the final destination of a product is recommended, as this affects performance. It should be explored why a product will be sent back to the store or returned to the warehouse to be handled. This research shows that the largest share of returned items is redirected to stores for particular home pick-ups in this case study. For returns through collection points, this percentage is much lower. The research has shown that whether a product is directed to a brick-and-mortar store or a warehouse significantly impacts the performance of a return method. Gathering insight into how these decisions are made can lead to improved performance for the company and is therefore recommended as a potential area of future research.

Future research should be done to increase the adoption potential of textile recycling and overcome its current limitations, where both the technical and practical feasibility should be considered for fashion companies. The recycling rates are currently meager within the fashion industry, although this creates a better environmental impact than landfill or disposal [45, 52]. A technical recommendation is, therefore, to investigate textile recycling alternatives for fashion companies and improve this adoption potential for both used and unused products. Additionally, barriers and drivers should be explicit, and insights need to be created into how they can be overcome, contributing to increased adoption of the technique.

The final recommendation for future research is to investigate governmental policies' role in lowering the number of product returns in fashion and identify the most effective approach. Experts in the field have noted that to incentive change within the operations of fashion companies, governments either need to have a strict policy or there should be pressure from shareholders, primarily because of the high costs. This study has shown that financial support is essential for companies to improve the sustainability of their operations. It is recommended to investigate governmental policies' role in lowering the number of product returns in fashion and which approach would be most effective. This includes examining, for example, the most effective targets for recycling-, landfill-, and incineration rates to improve the environmental footprint of this industry while considering the economic feasibility for a company in terms of financial subsidies or investments. This will contribute to the adoption potential of textile recycling in the fashion industry and improve sustainability. Additionally, it is recommended to incorporate the designed CI and benchmark to investigate the effectiveness of implementing these policies and monitor the effects on companies' performances.

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A

Scientific research paper

The scientific paper starts on the next page.

Understanding the environmental impact of product returns in the fashion industry

The development of a Composite Indicator to provide insights into the environmental and economic impact of product returns for fashion companies

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Abstract

Purpose - With the ongoing rise of product returns in the fashion industry, exacerbating its GHG footprint when it should be lowered, this paper aims to provide a measurement tool for companies to improve the environmental impact of product returns while considering the economic costs. Companies do not have an understanding of the impact of these returns on their performances, resulting from a gap in research where an accurate measurement method lacks that includes all activities and return methods.

Design/methodology/approach - The returns process and the return methods were analyzed using a literature study and interviews with experts, resulting in a set of environmental and economic indicators. These indicators were aggregated in a Composite Indicator (CI) by rescaling, analytical hierarchy process, and multiplicative aggregation techniques. A benchmark for target performance was developed based on reduction targets of the European Commission, using rescaling, equal weighting, and multiplication and integrated into the CI. An uncertainty- and sensitivity analysis confirmed the model's robustness. A case study of a fashion retailer verified the model. A scenario analysis based on the PESTLE framework was used to validate the CI and benchmark. A company's performance measured was compared against the verified benchmark by calculating the performance gap.

Findings - The environmental and economic impact of the return methods for the base case was measured. The impact of the return methods was compared against the benchmark, which shows that home pick-ups have the smallest performance gap with the benchmark for this retailer. Instore returns have the largest gap with the benchmark, indicating worse company performance and lower compliance with the EC targets. The scenario analysis showed how companies could use this CI to compare return improvement strategies with each other and provided potential solutions for companies to improve their performance.

Research limitations/implications - For fashion companies, this research provides a tool to measure, analyze, and improve the environmental impact of returns on their performances with EC reduction targets while considering their costs and providing transparency. Customers and governments are provided with transparent information on what- and how the environmental impact of returns is measured by a company. Governments can use the CI and benchmark proposed in this paper as a transparent tool for environmental reporting and compare the performances of companies sector-wide. For academics, this research provides multiple research opportunities.

Originality/value - This paper contributes by creating a new CI for company performance measurement for fashion companies on the environmental and economic impact of product returns. A new measurement method that assesses the environmental and economic impact of the return activities is developed and gives insight into the differences between the return methods. Also, a new benchmark expressing target performance is developed and incorporated in this CI based on reduction targets of the EC to combat climate change.

Keywords: Composite indicator, product returns, fashion industry, environmental performance, economic performance, performance measurement, target benchmark

ACRONYMS

3PL Third Party Logistics Provider

AHP Analytical Hierarchy Process

CI Composite Indicator

CR Consistency Ratio

UA Uncertainty Analysis

SA Sensitivity Analysis

GHG Greenhouse Gas

EC European Commission

EF Emisison factor

EW Equal Weights

EU European Union

LCA Life Cycle Assessment

LIN Linear aggregation

GME Geometric mean

I. INTRODUCTION

The fashion industry is a worldwide driver for economic growth [34]. With a growth rate of 9.93% per year (CAGR 2023-2027) [67], further growth in demand is expected in the years to come, particularly within e-commerce [7, 34, 42]. At the same time, the fashion industry's impact ranks the fourth largest on climate change within the European Union (EU), and action is needed to lower its environmental footprint [24, 31, 71]. As part of the Green Deal, the European Commission (EC) plans on mandatory environmental reporting, in which companies need to provide transparency on their performances [23]. Most research and efforts focus on sustainability practices in the forward value chain [3]. Less attention is paid to returns, although these have become an increased problem in this industry, particularly [6, 11, 72].

High return rates are observed, which are expected to increase further due to the industry's growth [1, 11, 68]. Besides economic losses for companies, these returns create additional Greenhouse Gas (GHG) emissions and waste, thereby negatively affecting society and the environmental footprint of companies [11, 18, 59, 68, 75]. The EC recognizes the environmental impact of returned products as a widespread problem within the EU [27], and actions should be taken to combat climate change [24, 75].

To do so, the GHG emissions created by returns should be reduced by improving the return process and lowering the number of returns [11, 24], leading to environmental gains for society and potential cost savings for companies [77].

Companies need an understanding of the environmental and economic impact of returns and how this affects their performances. With this, companies can design effective strategies to improve their environmental impact while remaining economically viable [8, 11, 71, 80]. However, companies do not yet have the tool to analyze, assess, and compare the impact of product returns and return methods on their environmental and economic performances, as an accurate measurement method lacks [11, 72]. In the scarce attempts to assess product returns, not all relevant logistic activities involved in a return are considered, assess not all GHG emissions, or consider not all return methods available nowadays. As a result, companies cannot measure and monitor their performance, identify areas of improvement, and design effective return improvement efforts to improve the impact of returns. Also, companies lack insights into how far they are in reaching the goals of the EC to combat climate change, although they need to comply with this [21, 23, 31]. Moreover, as this knowledge is lacking for companies, companies cannot provide information on the environmental impact of their returns to customers or governments. This leaves reduction potential unexplored, as informed customers will be more likely to make more sustainable decisions for their choice of return method [4, 7, 80] and limit opportunistic returns, thereby returning fewer products [8, 77]. This is expected to lead to both environmental gains for society and potential cost savings for a company.

The research question answered in this paper is: How can a Composite Indicator (CI) be constructed to provide insight into the environmental and economic performance of product returns against a target benchmark for fashion companies and help improve their sustainability?

This research has developed a new performance measurement tool for fashion companies to measure, analyze, and evaluate returns' environmental and economic impact. A new CI was constructed to measure the performance of returns on environmental and economic dimensions [82]. The CI included all return activities, considered the differences in the return methods, and assessed the environmental impact on a company's performance, thereby filling the research gap. The designed CI expanded the field of company performance measurement by assessing both environmental and economic performance, which was not done frequently yet [81]. In addition, a new benchmark based on GHG reduction targets of the EC for 2030 was designed, developed, and integrated into this CI. With this, a transparent and sector-wide tool was developed that companies can use to see how closely their performances comply with EC targets. Furthermore, governments can use this transparent tool to compare companies' performances with each other, as it is known what- and how the impact is measured, and evaluate their progress as part of the prospected EU mandatory environmental reporting. Next, governments can use this new benchmark to set more concrete targets to combat climate change sector-wide.

First, the returns process is presented using a literature review supplemented by interviews with industry experts in section II. CI are tools to measure performance, which supports companies in measuring and tracking progress and identifying potential areas for improvement in processes [40, 47, 51]. The findings on the return process are combined with literature and reports for constructing CIs and benchmarking, which are used to construct the CI and the benchmark in section III. Next, the CI and benchmark are applied to a case study, and the results are presented in section IV. Next, a discussion on the model is given in section V. Last, conclusions and recommendations for further research are made in section VI.

II. LITERATURE REVIEW

First, the process of returns is outlined, followed by a review of the environmental impact of return activities and the economic impact.

A. How the process of returns works

This research focuses on the whole process of a return and considers all logistic activities that are crucial in analyzing the environmental and economic impact. The boundary defined for the process of product returns in this research starts from the customer requesting a return until the recovery and disposition of the product is executed [6, 15]. Four phases are distinguished: return preparation, collection, processing and handling of returns, and product recovery and disposition, which is visualized in Figure 1.

Fashion companies use in-store returns, collection point returns, or home pick-up returns. The availability of the return methods for a customer depends on whether the retailer offers this service [5]. Packaging is needed for safe transport when a collection point or home pick-up is selected. Product transport occurs to the final recovery point, depending on the return method. This final recovery point can be the brick-and-mortar store, where it will be restocked again, or the warehouse [6, 15]. If the product's final destination is the warehouse, it will be recovered. The choice for a recovery treatment is based on several criteria, including the cost, the product market value, added value of recovery, and the type of product [44].

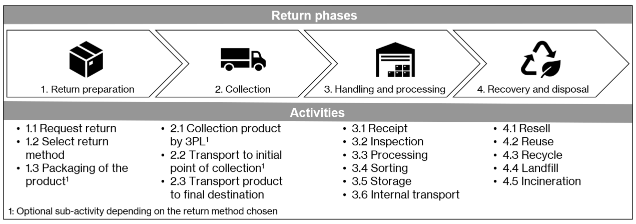

FIG. 1: Return processes and sub-activities, adapted from [14]

B. How a product return creates environmental impact

The GHG Protocol and the Life Cycle Assessment (LCA) are presented as assessment tools for environmental impact in literature. A LCA is used when measuring a more comprehensive set of environmental factors and evaluating the overall effect of a product throughout its entire life cycle [54]. The GHG Protocol is more useful when measuring specific activities and is commonly used as an accounting tool at the company levels for activities in its value chain [35]. This study aims to measure the GHG emissions created by all activities in the return process, making the GHG Protocol more suitable as a measurement tool to assess the environmental impact of product returns for this research.

The GHG Protocol is a recognized tool by the EC for measuring and reporting GHG emissions and provides a standardized methodology by using Emisison factor (EF)s that incorporate the GHG emissions per activity or process [35, 36].

The following sources of emissions are identified from the literature: packaging emissions, transport emissions, warehouse and equipment emissions, brick-and-mortar store emissions, and product recovery and disposal emissions.

Packaging emissions are created when a customer returns by home pick-up or collection point or when the product gets transported from the brick-and-mortar store to the warehouse. Packaging emissions consist of usage and waste emissions. The magnitude of the usage emissions depends on the type of packaging material, the mass of the packaging, and whether or not a customer reuses the packaging for their return [36, 69]. The packaging waste emissions depend on the waste treatment chosen, the type of packaging material, and the mass [36, 69].

Transport consists of short- and long-haul activity [36]. The transport emissions depend on how a product is returned, as for each return method, a different journey is considered [13, 19, 49, 59]. The transport emissions created by in-store returns depend firstly on the trip from the customers' location to the store and back [9, 19, 49, 79], and optionally the transport activity from the brick-and-mortar store to the warehouse [14]. This depends on the distance driven, product mass, and vehicle characteristics [36]. For home pick-ups, the whole pick-up journey needs to be considered. Based on the locations of the pick-up requests and the distribution center, a vehicle journey is constructed from the pick-up point to the initial recovery point [13]. After the vehicle arrives at the recovery point, the products are redistributed to their final recovery destination (i.e., the warehouse or brick-and-mortar store), creating additional transport emissions [36]. The transport emissions for collection point returns can be measured by distinguishing three transport activities. First, from the customer to the collection point; second, the journey of the Third Party Logistics Provider (3PL) from the collection point to the distribution center, where the journey distance depends on the location of the collection points served in that journey and the distribution center. Third, the product needs transportation to its final destination, intensifying the transport emissions of the collection-point return.

Warehousing includes multiple activities (see Figure 1), intensifying the environmental impact [49, 63]. The main contributors to warehouse emissions are the fuel and electricity consumed [49, 63]. In addition, internal transport and the energy used by warehouse equipment for handling facilities must be considered, depending on the equipment type used and operation time [63]. If products are handled in-store, the environmental impact created here must be considered [36]. This depends on the store size, location, and energy rating [49].

Products can be resold, repaired, recycled, remanufactured, or sent to incineration or landfills [2, 15, 32, 44]. The chosen recovery or disposition strategy affects the GHG emissions of a product [6, 28, 36].

C. How a product return creates costs

The economic impact of product returns is measured based on the activities performed by a company to perform a return and the return methods [48]. According to an industry expert, this activity-based approach is commonly used in practice.

Costing of return-related activities includes transportation, labor, handling equipment, disposition, and storage of the products and packaging [39, 46], and is confirmed by two experts.

Depending on how the product is returned, transport costs are created. In-store returns only generate transport costs for a company when the decision is not to resell the product in-store. Also, the transport is usually outsourced to a 3PL but can be self-executed, affecting the cost structure [14]. The main components of transport costs are the distance, the vehicle load, the mass of the product, and fixed- and variable modality costs [15, 39, 73].

Warehousing and equipment costing depends on the space and resources needed, storage time, and leasing costs [14]. Operating costs of the physical store should be considered for returns handled in-store. According to an expert, the most significant cost factor is the leasing costs of the stores. Returns are highly labor intensive, and labor costs are incurred in brick-and-mortar stores and warehouses. Activities include receiving, inspecting, and restocking products [39]. The product return labor cost on an annual basis is the sum of these fees [39]. Additionally, this metric should include any overhead expenses and investments like training or other employee benefits in this metric [14].

Recovery costs are included for both packaging materials and the product itself. These recovery costs per item are calculated by the mass of the item, the recovery charge, and optional transport charges, depending on the country of disposal [20, 29]. Governmental charges are associated with landfill and incineration, which come at the cost of a company [41].

III. CONSTRUCTION OF THE CI

A new CI was constructed for a multi-dimensional assessment of product returns on the performance of fashion companies, including the development and integration of a target benchmark. The CI should give a complete assessment of the impact of returns, including all return methods and activities; it needs to be straightforward to use by companies and transparent; the results should be easy to be communicated; and companies should know how far they are in reaching certain goals, thereby increasing the value of this measurement tool [82]. The construction was split into four phases, as can be seen in Figure 2. A case study was used to complete phase 4.

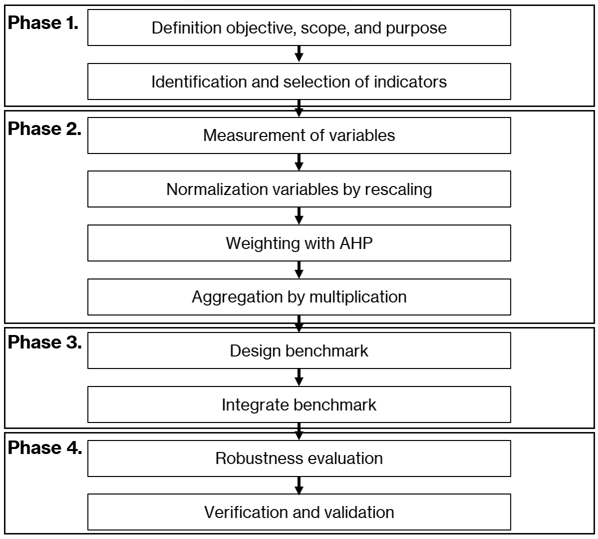

FIG. 2: Conceptual model construction CI with benchmark, source: (Author)

A. Phase 1. Theoretical framework with variables

The theoretical framework for assessing product returns is presented in Table I. The final selection avoided double-counting of emissions or costs between the indicators and fulfilled the objective and scope of the research. Variables 1-5 are the environmental set of indicators, and variables 6-10 are the indicators for the economic dimension. All variables have a negative indicator variability, which indicates that a lower value of that respective variable is preferred to obtain higher performance [62, 83].

TABLE I: Theoretical framework of the variables, source: (Author)

	Description	Unit of measurement
V_1	Packaging emissions	$\frac{kgCO2e}{returned\ product}$
V_2	Transport emissions	$\frac{kgCO2e}{returned\ product}$
V_3	Warehouse and equipment emissions	$\frac{kgCO2e}{returned\ product}$
V_4	Product recovery emissions	$\frac{kgCO2e}{returned\ product}$
V_5	Brick-and-mortar emissions	$\frac{kgCO2e}{returned\ product}$
V_6	Transport costs	$\frac{euro}{returned\ product}$
V_7	Labor costs	$\frac{euro}{returned\ product}$
V_8	Warehouse and equipment costs	$\frac{euro}{returned\ product}$
V_9	Recovery costs	$\frac{euro}{returned\ product}$
V_{10}	Brick-and-mortar costs	$\frac{euro}{returned\ product}$

B. Phase 2. Development of the CI

The CI was constructed using several techniques that were selected based on the requirements for this CI, its objective, and scope [50, 56]. For aggregation, the multiplication technique was used. This technique is easy to interpret and allows for partial compensability between the indicators, meaning that, to some extent, trade-offs can be made between the variables [52]. A partial compensatory approach was most appropriate rather than complete compensability considering the requirements and theoretical framework in this assessment [50, 52, 53]. The weights were constructed with Analytical Hierarchy Process (AHP), which allows for relative weighting of the variables. Also, it allowed decision-makers to make company-specific trade-offs between the variables but provided a statistical method to construct the weights [38, 55]. As AHP was selected, [50] suggests using either a ranking, standardization, or rescaling transformation method for normalization. The ranking was unsuitable in this study as it cannot provide differences in performances [70], z-score was unfeasible with multiplication aggregation, so rescaling was selected [56]. Rescaling is simple and can widen ranges variable intervals but is less capable of maintaining proportionally [56].

1. *Measurement of the variables*

Variables were measured using methods derived from literature and interviews.

The emissions of packaging waste (V_1) were determined by the total mass of packaging material m_m multiplied by the waste-treatment-specific EF, see Equation 3.1 [36, 69].

$$V_1 = m_m * EF_{\mathrm{wt}} \tag{3.1}$$

The transport emissions were calculated by the total distance driven with a modality [36, 37], represented in Equation 3.2. Here, d represents the distance, m_p the mass, and EF an EF based on the modality [19, 49, 79]. A constant fuel consumption per traveled kilometer is assumed [13]. For the in-store vehicle journey and the collection point journey, a general vehicle routing problem with a single warehouse was assumed to be the underlying transport model, in which several conditions were respected [10, 13, 16, 76]. The capacity of the vehicle or time limitations limits the vehicle's journey. Additionally, it was assumed that a customer's request must be served in one visit [10, 15, 76]. The vehicle departs at the warehouse and ends its journey at the same location, of which the origin and destination were represented by nodes *0* and *n+1*, and n the demand nodes. For home pick-ups, the vehicle journey was calculated by Equation 3.3, with $i, j \in P$, with P the set of pick-up points [10, 13, 16, 76]. To calculate the transport emissions of a collection point journey, Equation 3.4 was used, in which the distance was measured between the collection points, $i, j \in C$, with C [13]. The return requests were represented by demand nodes n, and the arcs represent the actual distance d_{ij} from node i to node j.

$$V_2 = \sum d * m_p * EF_m \tag{3.2}$$

$$V2_{pick-up} = (\sum_{(i,j)\in P} d_{ij} + d_{0,i} + d_{j,n+1}) * m_p * EF_m \tag{3.3}$$

$$V2_{collection-point} = (\sum_{(i,j)\in C} d_{ij} + d_{0,i} + d_{j,n+1}) * m_p * EF_m \tag{3.4}$$

An environmental impact study of warehousing of [63] links the size of the warehouse to energy consumption and the geographical location of the warehouse. The warehouse and equipment emissions were calculated by Equation 3.5, where A is the area dedicated to returns at the warehouse, EF_{wh} the EF for warehousing, c_{eq} the costs of equipment for a year, EF_{eq} the EF for equipment usage, and n the number of products handled at the warehouse over the considered time period [35, 36].

$$V_3 = \frac{(A_w * EF_{wh}) + (c_{eq} * EF_{eq})}{n} \tag{3.5}$$

The calculation of GHG emissions for this phase of the return process was defined for the chosen recovery method [6]. Recovery emissions are measured with Equation 3.6, with an EF for the waste treatment chosen and m_p the mass of the product [28, 36].

$$V_4 = m_p * EF_{wt} \tag{3.6}$$

Based on the average time a product spends at the store, and the number of products handled in the store over time, the in-store emissions allocated to a product return can be determined [36]. This is captured in Equation 3.7, where A_s is the area of the brick-and-mortar store, EF_s a store-specific emission factor that expresses the energy usage in GHG emissions, and n the number of products handled in store over a considered time period [49].

$$V_5 = \frac{A_s * EF_s}{n} \tag{3.7}$$

The transport costs were calculated with Equation 3.8, where d is the distance driven, m_p the product mass, and c_t includes modality-specific factors expressed per ton-km distance driven [15, 39, 73].

$$V_6 = \sum d * m_p * c_t \tag{3.8}$$

The calculation of [39] was adapted to Equation 3.9, which expresses the total labor costs per returned item. Here, c_{res} is the costs for inspection and restocking per product, c_{rec} is the cost of receiving per item, and c_{overh} is the overhead expenses per product [14, 39].

$$V_7 = c_{\text{res}} + c_{\text{rec}} + c_{\text{overh}} \tag{3.9}$$

The warehouse and equipment costs are determined with Equation 3.10, where c_{wh} are the leasing cost of the warehouse over a considered period [14].

$$V_8 = \frac{(A_w * c_{wh}) + c_{eq}}{n} \tag{3.10}$$

The recovery costs were calculated by Equation 3.11, where both the product return and packaging material are considered. The costs for recovery depend on the chosen treatment of waste and the country where it is processed [12, 20, 29].

$$V_9 = (m_p * c_{rec,p}) + (m_m * c_{rec,m}) \tag{3.11}$$

Operating costs of the physical brick-and-mortar store should be considered for in-store returns. From interviews, it follows that the most significant cost factor within this metric is the leasing costs of the store. The costs per unit product can be estimated by obtaining the total number of products handled at the store over a certain period, as presented in Equation 3.12. Here, c_s are the costs per m2, A_s the total store area, and n is the number of products handled in store over a time period.

$$V_{10} = \frac{c_s * A_s}{n} \tag{3.12}$$

2. *Normalization*

The indicators are normalized so they can be compared regardless of their different unit of measurement. This is done by rescaling using Equation 3.13 [81]. Here, $min_i(x_{ij})$ and $max_i(x_{ij})$ are the minimum and maximum values for indicator j considering all return methods i [70].

$$I_{ij} = 1 + \frac{max_i(x_{ij}) - x_{ij}}{max_i(x_{ij}) - min_i(x_{ij})} \tag{3.13}$$

Where:

- i The return method i, $i = \{1, ..., n\}$
- j The value of indicator j, $j = \{1, ..., m\}$
- x_{ij} The raw value of indicator j for return method i
- I_{ij} The normalized value of x_{ij}

3. *Weighting*

The variables were relatively weighted with the AHP technique, which allows decision-makers to make trade-offs between pairs of variables[56]. First, the decision maker decides which variable in the considered pair is more important. Second, the decision maker expresses how much more preferred this variable is by assigning a score on a semantic scale that ranges from 1 to 9 [55, 58, 64, 65]. A value of 1 (weak preference) is given when both indicators are equally important, a five corresponds to a strong preference, and a 9 expresses an extreme preference for one variable over another [57].

These preferences are combined in a reciprocal pairwise comparison matrix A (n x n), where the $a_{ii} = 1$ and $a_{ji} = 1/a_{ij}$ should be met [74]. Each element a_{ij} expresses the relative preference assigned by the decision maker for alternative i to j, where the alternatives represent the variables [57, 64]. Next, the relative weights for each variable will be calculated by the principal right eigenvector approach of matrix A [57, 64]. Then, the consistency in the judgments of the weights needs to be ensured by reaching an acceptable level of consistency, which is determined by Equation 3.15 [43, 66]. Here, λ_{max} is the maximum eigenvalue, n is the number of variables, and RI can be derived from the random consistency index of [57, 81]. The Consistency Ratio (CR) should be below a threshold value, which is 0.10 with n>=5 [57, 66].

$$A = [a_{ij}] = \begin{bmatrix} 1 & a_{ij} & \dots & a_{1n} \\ 1/a_{ij} & 1 & \dots & a_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ 1/a_{1n} & 1/a_{2n} & \dots & 1 \end{bmatrix} \tag{3.14}$$

$$CR = \frac{\lambda_{max} - n}{(n-1) * RI} \tag{3.15}$$

TABLE II: RI values corresponding to the number of variables n, from [57]

n	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
RI	0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49	1.51	1.48	1.56	1.57	1.59

4. *Aggregation*

The indicators are aggregated with multiplication aggregation (also Geometric mean (GME)), which provides an in-between solution between the full and non-compensability of the different variables. By multiplying the weights and normalized indicators, a value of the CI is obtained that reflects the relative importance of each indicator and how much an individual indicator contributes to the total score of the CI [81, 83].

The previously calculated functions are used as input for the formula for aggregation (Equation 3.16). In this equation, w_j expresses the weight of indicator j for product return method i. I_{ij} is the normalized value of indicator j for return method i. CI_i expresses the value of the CI for return method i [81].

$$CI_i = \prod_{j=1}^{10} I_{ij}^{w_j} \tag{3.16}$$

C. Phase 3. Construction of the benchmark

A new benchmark is designed, constructed, and integrated into this CI, expressing target performance. Benchmarking can identify performance gaps and is, therefore, a commonly used method in addition to performance measurement [81, 82]. The benchmark is designed using the Political and Legal criteria from the PESTLE analysis (Political (P), Economic (E), Sociological (S), Technological (T), Legal (L), and Environmental (E)) [61, 78]. European companies should comply with their performances with legislation and policy-making decisions, which therefore drive company improvements.

The benchmark is set for the year 2030. This will represent the shorter-term goals of a company in its net-zero journey for 2050, which are more tangible and more accessible for companies to achieve as it is less than a decade away. Also, shorter-term goals allow companies more flexibility in their strategies for achieving them. The reduction targets are obtained through reports and official publications of the EC. Companies need to reduce their emissions according to reduction targets set by the EU. These targets are translated into company-specific values for the benchmark with data from that company. There are no targets set for the economic indicators, as making any accurate assumptions on the benchmark costs for 2030 is impossible. These costs are embedded with uncertainty, and making any assumptions to this end would negatively affect the reliability of the benchmark. For this reason, the base case costs for the economic benchmarks are applied in this research.

- Packaging should be made of recycled materials by 2030. The packaging recycling rate for cardboard should be 85% and for plastic 55% in 2030. Packaging materials sent to landfills should decrease to 9.6% by 2030 [25, 28]. It is assumed that the remaining packaging material is combusted.
- The target value for transport emission reduction by the EC is set at 55% by 2030 compared to the base year 1990, which was accepted in 2020 [30]. Assuming a linear reduction rate, this would mean a yearly GHG-emission reduction of 1.57% from 1995-2030, which is applied.
- The EC has put a benchmark of 32% of renewable energy sources in buildings by 2030, which will be the target value for warehouse- and brick-and-mortar energy usage in the benchmark in this research [22]. Electricity produced by renewables should power warehousing equipment as well in 2030.
- Incineration and landfill should be limited to 1% of the total waste treatments, and a reduction of overall disposal emissions of 30% by 2030 should be met [24, 26, 28, 45].

The benchmark is constructed by rescaling, Equal Weights (EW), and aggregation by multiplication. Instead of AHP, EW is applied to improve the generalizability and transparency of the benchmark. The aggregated results of the CI, representing the company's performance, were compared with the target performance by analyzing the performance gap M. The performance gap is determined with Equation 3.17, where a lower value of M represents better performance, where CI_b is the benchmark performance and CI_a is the actual performance of a company [17].

$$M = CI_b - CI_a \tag{3.17}$$

D. Phase 4. Robustness evaluation of the CI

Insight into how- and to what extent the final value of the CI was affected by a source of uncertainty for building the CI [33, 70] is obtained by inspecting uncertainty triggers by uncertainty- and sensitivity analysis [56]. The triggers analyzed were X_1 rescaling weights, X_2 use of a different aggregation method, and X_3 varying the input data. The normalization method was not analyzed as the rescaling method is the only appropriate normalization method for this CI. The weights were rescaled, Linear aggregation (LIN) was adopted for aggregation, and uncertainty sources in the input data were increased- and decreased by 25%, while the rest remained unchanged.

The model was tested with a case study and a scenario analysis based on the PESTLE framework [61, 78]. This scenario analysis served as a tool to test the models' performance.

IV. RESULTS

First, an introduction was given to the experiment settings. Next, the results were presented of the performance of the different return methods.

A. Experiment settings

1. Case study

Data was retrieved from an international fashion retailer, mainly active in the downstream supply chain.

The data consisted of 6388 returned products from customers in the Netherlands in the base year. The retailer offers in-store returns, home pick-ups, and collection point return services. The retailer's brick-and-mortar store is located in the Netherlands, and the warehouse for returns is in Spain.

2. Scenario set-up

Scenarios were created with PESTLE. A moderate and extreme variant was developed for each scenario based on literature studies, reports, and expert insights. The scenarios are implemented in the model to test its performance.

- Scenario 1. Shifting customer behavior (PE**S**T**LE**)
  Drive by more conscious customer behavior, less opportunistic returns, choice of return method based on environmental impact, reuse packaging box, recycle packaging, financially discouraging customers by a return fee.
- Scenario 2. Green supply chain management (PESTL**E**)
  Driven by stakeholder engagement, adoption of electric vehicles, short-haul transportation, LNG-fueled long-haul transportation, renewable energy for buildings and warehouses, financial compensation costs in a return fee.
- Scenario 3. Economic attractiveness of renewables (P**E**STLE)
  The rise in fossil fuel prices, increased use of renewables and green transportation, and financial government support.
- Scenario 4. Governmental support for circularity (**P**EST**L**E)
  Extended Producer Responsibility, higher recycling rates for packaging material, lower landfill/incineration rates, and financial support from the government.
- Scenario 5. Technological innovations (PES**T**LE)
  More efficient transport, better online shopping experiences, fewer in-store operations, and more e-commerce increased the recycling potential of clothing.

B. Performance measurement with the CI

The raw values for each indicator for the return methods and the benchmark are shown in Table III, normalized in Table IV. The weights were derived from the reciprocal matrix in Table V, which expressed the relative preferences of the decision makers between each pair of variables. This resulted in the weights presented in Table VI, satisfying the reciprocal constraints with CR below 0.1.

Table VIII showed the aggregated value of the CI scores of each return method. A higher value of the CI represented better performance, and a lower value indicated worse performance. Based on the data of this retailer, the in-store return method scored lowest among the return alternatives, and the home pick-up scored best in terms of environmental and economic performance. The largest differences between the return methods are within the environmental performance, as seen in Table VII. The base case overall performance is the average of the return methods, which comes close to the CI score of the collection point returns. This is because almost all returned items are returned through collection point returns for this retailer (92.45%).

Next, the performance gaps with the benchmark are calculated, where a lower value represents better performance [17]. As seen in Table IX, if home pick-up returns a product, the company's performance comes closer to the target performance than when a customer uses other return methods. The differences between the performance of the return methods is visualized in Figure 3. Higher values result in better performance, corresponding to values more on the outside of the axis in the radar. Values closer to the center are less preferred in terms of performance. This shows that the benchmark outperforms almost all return methods on the environmental indicators, identifying areas for improvement for the company to comply with EC targets. Companies use these insights to define improvement strategies that target specific measures. Although in-store returns score best on packaging emissions, transport costs, and brick-and-mortar costs, the aggregated results show that this return method is not advantageous to improve the overall performance of a company. When a company focuses on improving transport emissions, it is interesting to use home pick-ups more often for returns, as this method lowers the performance gap with the benchmark.

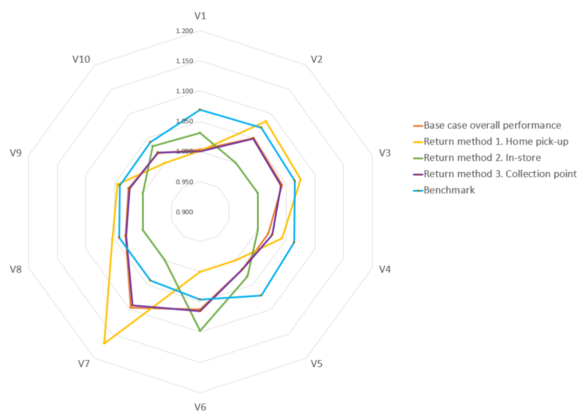

FIG. 3: Radar chart base case with the benchmark, source: (Author)

TABLE III: Raw indicator values base case with the benchmark, source: (Author)

	V_1 [kgCO2e/ returned product]	V_2 [kgCO2e/ returned product]	V_3 [kgCO2e/ returned product]	V_4 [kgCO2e/ returned product]	V_5 [kgCO2e/ returned product]	V_6 [euro/ returned product]	V_7 [euro/ returned product]	V_8 [euro/ returned product]	V_9 [euro/ returned product]	V_{10} [euro/ returned product]
Benchmark	0.016	**14.498**	0.743	0.007	**0.484**	0.230	12.379	5.096	0.523	1.903
Base case overall performance	0.075	32.217	1.092	0.012	0.712	0.230	12.379	5.096	0.523	1.903
Return method 1. Home pick-up	0.077	23.721	**0.624**	**0.005**	**0.784**	**0.432**	**7.076**	**4.721**	**0.280**	**2.093**
Return method 2. In-store	**0.013**	**42.567**	**1.559**	**0.016**	0.642	**0.073**	**17.666**	**5.470**	**0.755**	**1.715**
Return method 3. Collection point	**0.078**	32.592	1.118	0.010	0.710	0.217	12.673	5.117	0.539	1.896

TABLE IV: Normalized values base case with the benchmark, source: (Author)

	V_1	V_2	V_3	V_4	V_5	V_6	V_7	V_8	V_9	V_{10}
Benchmark	1.950	2.000	1.873	1.860	2.000	1.563	1.499	1.499	1.487	1.504
Base case overall performance	1.055	1.369	1.499	1.345	1.238	1.563	1.499	1.499	1.487	1.504
Return method 1. Home pick-up	1.024	1.671	2.000	2.000	1.000	1.000	2.000	2.000	2.000	1.000
Return method 2. In-store	2.000	1.000	1.000	1.000	1.473	2.000	1.000	1.000	1.000	2.000
Return method 3. Collection point	1.000	1.355	1.471	1.507	1.246	1.598	1.471	1.471	1.454	1.520

TABLE V: Reciprocal comparison matrix, source: (Author)

	V_1	V_2	V_3	V_4	V_5	V_6	V_7	V_8	V_9	V_{10}
V_1	1	$\frac{1}{4}$	$\frac{1}{2}$	$\frac{1}{2}$	1	$\frac{1}{4}$	$\frac{1}{3}$	$\frac{1}{2}$	$\frac{1}{2}$	1
V_2	4	1	2	2	3	1	$\frac{1}{2}$	2	2	6
V_3	2	$\frac{1}{2}$	1	3	2	$\frac{1}{2}$	$\frac{1}{2}$	1	2	3
V_4	2	$\frac{1}{2}$	$\frac{1}{3}$	1	$\frac{1}{3}$	$\frac{1}{2}$	$\frac{1}{3}$	$\frac{1}{2}$	$\frac{1}{2}$	3
V_5	1	$\frac{1}{3}$	$\frac{1}{2}$	3	1	$\frac{1}{2}$	$\frac{1}{4}$	3	2	1
V_6	4	1	2	2	2	1	$\frac{1}{3}$	2	2	3
V_7	3	2	2	3	4	3	1	3	6	2
V_8	2	$\frac{1}{2}$	1	2	$\frac{1}{3}$	$\frac{1}{2}$	$\frac{1}{3}$	1	2	1
V_9	2	$\frac{1}{2}$	$\frac{1}{2}$	2	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{6}$	$\frac{1}{2}$	1	2
V_{10}	1	$\frac{1}{6}$	$\frac{1}{3}$	$\frac{1}{3}$	1	$\frac{1}{3}$	$\frac{1}{2}$	1	$\frac{1}{2}$	1

C. Scenario testing

This section evaluates the performance of the different scenario designs (see section IV A 2). The results of the performance gaps with the benchmark are visualized in Figure 4, where the height of the column represents the performance gap relative to the benchmark. The largest gap is found in the extreme variant of scenario 3; the economic attractiveness of renewables. The extreme variant of scenario 1 has the smallest performance gap with the benchmark relative to the other scenarios, indicating better performance.

The results show that the most considerable improvements in overall performance can be achieved when fewer products are returned due to more conscious behavior and, on the other hand, a higher recycling rate of packaging materials is achieved. Additionally, a return fee to discourage customers from returning items also leads to performance improvements relative to the base case, closing the gap with the benchmark. This is a crucial component to lower the costs of returns when no governmental support is given. The scenario analysis shows the importance of the financial support of governments for companies to ensure feasibility in company efforts to improve their environmental impact. Adopting less harmful waste treatments that enhance circularity shows improvements in environmental areas but are slightly higher in costs, affecting the overall performance. The gains achieved by technological innovations depend on the availability of technology and economies of scale that might help to lower costs, shrinking the performance gap with the benchmark.

TABLE VI: Weights derived by AHP, source: (Author)

	Weight
V_1	0.044
V_2	0.158
V_3	0.104
V_4	0.060
V_5	0.085
V_6	0.134
V_7	0.228
V_8	0.075
V_9	0.063
V_{10}	0.048

TABLE VII: Environmental performance score and economic performance score of the return methods, source: (Author)

	Environmental performance score	**Economic performance score**
Base case overall performance	1.334	1.513
Return method 1. Home pick-up	**1.545**	**1.588**
Return method 2. In-store	**1.150**	**1.260**
Return method 3. Collection point	1.339	1.504

V. DISCUSSION

A. Robustness evaluation of the CI

Each uncertainty trigger was implemented in the CI, and its effect on the final value of the CI using base case data were inspected and statistically tested using the Pearson correlation coefficient [60, 81]. The Uncertainty Analysis (UA) has concluded that a strong correlation ex-

TABLE VIII: Aggregated CI scores with benchmark, source: (Author)

	CI score
Benchmark	1.710
Base case overall performance	1.430
Return method 1. Home pick-up	**1.568**
Return method 2. In-store	**1.209**
Return method 3. Collection point	1.427

TABLE IX: Performance gap base case with the benchmark, source: (Author)

	Performance gap M
Base case overall performance	0.280
Return method 1. Home pick-up	**0.142**
Return method 2. In-store	**0.501**
Return method 3. Collection point	0.283

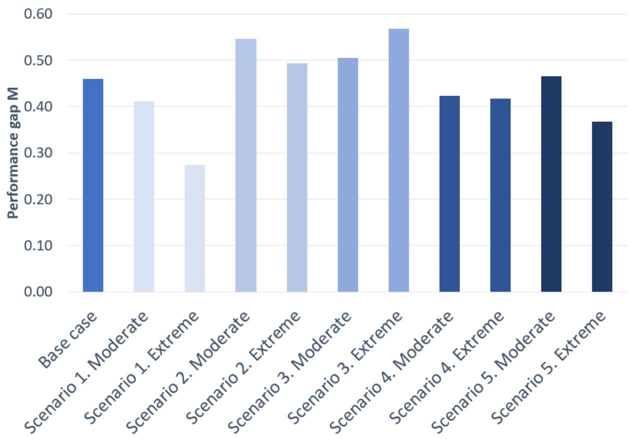

FIG. 4: Performance gaps scenarios relative to the benchmark, source: (Author)

ists between the constructed model and the alternative construction methods, indicating that using a different method leads to similar results. Also, uncertainty in the CI resulting from assumptions in the input data was analyzed using a Sensitivity Analysis (SA). This evaluation revealed that the model's output is robust to changes in data, reflecting the resilience of the CI.

B. Verification

The CI was successfully verified through a structured walkthrough, and the model's output was inspected by testing it with a base case. First, the calculation of the variables was inspected and checked on how they were computed, and a consistency check was done on their units of measurement. Second, the formulation and equations for rescaling, weighting, and aggregation were reviewed. Thirdly, the reliability of the model's output and set-up of the benchmark was inspected. The benchmark's set-up was verified using the verification framework PESTLE and through expert consultation. Next, it was checked whether the benchmark was implemented correctly to verify the reliability of the model's output. The benchmark was tested using performance analysis tools from the literature, which showed plausible results aligned with the expectations, and no surprises were found. The model's output showed that the model could find what needs to be understood, and the CI can be successfully verified.

C. Validation

Conceptual validation of the model took place by investigating the model's behavior and correctness through a scenario analysis. Five scenarios were developed with the verification tool PESTLE and expert insights, which improved the reliability of the scenarios with real-life developments. Implementing the scenarios in the model has shown that it can provide desired outputs, serve its purposes, and create valuable insights, validating the model and benchmark.

VI. CONCLUSION AND FUTURE RESEARCH

A. Conclusion

This research has created a new CI to measure the impact of product returns on the environmental and economic performance of fashion companies and created an understanding of this to improve their environmental footprint. A new benchmark was designed based on GHG reduction targets of the EC for 2030 which was developed and integrated into this CI to help companies improve sustainability.

The first scientific contribution of this research was that scientific research was added to the underexplored topic of product returns in the fashion industry, focusing on the effects and potential solutions of consumer product returns' environmental and economic impact. The second contribution was developing a measurement method for a complete assessment of the GHG emissions and costs of product returns, including all activities and return methods. Third, an overview was created to compare return methods based on their performance, which was lacking [7]. Fourth, a new CI was constructed for fashion companies to measure their performance, including designing and developing a new benchmark expressing environmental target performance. Last, both environmental and economic dimensions were included in this CI, thereby expanding research on this new type of company performance measurement by CIs [81].

Additionally, multiple practical contributions were made. Fashion companies can lower their environmental footprint- and costs by improving the returns process using the insights from the CI. Insight into the sources of GHG emissions and the costs of product returns were created, and how companies can measure them. Also, differences between the return methods and their performance were made explicit. Companies can use these combined insights to define, compare, and implement feasible strategies and well-informed decisions to improve sustainability, as both environmental improvements and economic risks were considered. Further, these insights created transparency on what- and how the environmental impact of returns was measured. This information can inform customers and create awareness of their return behavior. This leads to environmental and economic benefits for a company, as more conscious return choices are likely to be made, and opportunistic return behavior can be limited. Further, knowledge was created for companies to know how far they are in reaching the goals of the EC to combat climate change as they can measure and track their progress relative to these targets. With this, a transparent and sector-wide tool was developed that companies can use to see how closely their performances comply with EC targets, and governments are provided insight into how- and what environmental is measured. Governments can use this tool to compare companies' performances with each other and evaluate their progress as part of the prospected EU mandatory environmental reporting or to set more concrete targets to combat climate change sector-wide.

B. Future research

This study has created the information needed to provide transparency and inform customers, but it does not analyze how- and where companies in the purchasing- and return process can use this information the best to encourage customers' conscious return decisions- and behavior most effectively. Therefore, it is recommended to develop a dashboard or digital twin where insights are obtained where- and how customers can best be encouraged using the insights obtained from this study. Further, it is recommended that companies mitigate the number of returns by adjusting the leniency of return policies. However, the potential effect on customer sales was left unconsidered in this study, forming the basis for the following possibilities for future research, which have both practical and scientific implications. First, the findings of this study should be incorporated to design new return policies, targeting lowering returns using financial discouragements based on the environmental impact created when returning a product. Research should be conducted into optimal financial discouragement while considering its effect on customer demand and a company's profitability. Also, exploring the efficiency of targeting specific product categories with their return policies is recommended, as some categories cause higher returns than others. The effect of the policies can be analyzed and tracked using the CI developed in this research. These insights may help companies adjust their return policies, contributing to lower returns and improved environmental impact. Following, investigating a company's decision-making process on the final destination of a returned product is recommended, as this affects performance. Future research should be done to increase the adoption potential of textile recycling and overcome its current limitations, where both the technical and practical feasibility should be considered for fashion companies. The final recommendation for future research is to investigate the most effective governmental support for companies in lowering their performance gap with the benchmark. Using the benchmark and CI to investigate the effectiveness of implementing these policies and monitor the effects on companies' performance is recommended.

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B

Preference scale of AHP

The AHP uses a preference scale to assign importance to a variable in each pair considered. The scale is expressed from 1 to 9, where each factor corresponds to a degree of preference [168, 160].

Table B.1: Preference/importance scale AHP, from [167]

Factor of preference	**Importance**
1	Equally preferred
2	Equally to moderately preferred
3	Moderately preferred
4	Moderately to strongly preferred
5	Strongly preferred
6	Strongly to very strongly preferred
7	Very strongly preferred
8	Very to extremely strongly preferred
9	Extremely preferred

C
Dimensions of a package

This Appendix gives insight into different packaging dimensions used for e-commerce in fashion. The measurement units of the variables are expressed per product, and the emissions generated in product returns must be allocated to one product return. Therefore it is necessary to specify the average dimensions used for a unit product return in this research. This will be done for an average fashion item. Small, medium, and large boxes are typically used for shipment in fashion e-commerce. For example, small boxes are mainly used for belts, jewelry, socks, and other small accessories. Medium-sized boxes are commonly used when transporting jeans, dresses, sweaters, or shoes. Larger parcels are suitable, for example, oversized winter coats, backpacks, or jackets [193]. Although jackets and coats can fall into larger-sized packages, most fashion items are relatively small and lightweight. For this reason, it is more likely that the average packaging size of a fashion product is a medium-sized package. This corresponds to a package mass of approximately 1 kilogram [193]. This research assumes the size of a cardboard box for product return of 22.9 x 22.9 x 22.9 cm (9 x 9 x 9 inches) with a mass of 0.279 kg [34]. For corrugated cardboard boxes, a mass of 0.227 kg is handled [185]. Although these box dimensions will be used as a standard for this research, it should be considered that the value for the product size can vary per company and product type.

These dimensions are also considered for plastic polybags with an average mass of 0.011 kg [188].

Table C.1: Dimensions for the most common sizes of packaging, adapted from [34, 185, 188]

Packaging type	Box dimensions [cm]	Weight [kg]	Database/Source
Cardboard	15.24 x 15.24 x 15.24	0.127	[34]
Cardboard	22.86 x 22.86 x 22.86	0.291	[34]
Cardboard	30.86 x 30.86 x 30.86	0.49	[34]
Corrugated cardboard	22.86 x 22.86 x 22.86	0.279	[185]
LDPE polybag	22.86 x 22.86 x 22.86	0.011	[188]

D

Context data

This Appendix provides an overview of the input data used to perform base case calculations and measurements.

Table D.1: Context data

Data description	Figures	Source	Assumptions/additional comments
Retailer features			
Warehouse size [m2]	6500	Client data	This warehouse is solely dedicated to handling product returns.
Store size [m2]	120	Client data	
Warehouse energy rating	n/a	-	
Store energy rating [A-G]	C	Client data	
Returns handled at the warehouse/year [#]	1.090.000	Client data	
Warehouse employees [#]	208	Client data	
Location store	NL	Client data	
Location warehouse	ES	Client data	
Products handled in-store/year [#]	-	Client data	
Logistics and transport features			
Returned products/year from the Netherlands [#]	6388	Client data	This number corresponds to the number of products delivered in the Dutch market of this retailer.
Transport modalities used	Road transportation	Client data	No further specifications given on the type of road vehicles.
Transport providers used	UPS, PostNL	Client data	
Average time for handling returns in store [min]	10	Expert consultation	The time to handle a return is between 5-15 minutes based on expert consultation, so the average of this is assumed as the input value.
Average time product spends at storage in warehouse	3-5 days	Expert consultation	This number is also in line with estimations done by [118]
Energy consumption			
Annual energy consumption [kWh/m2/year]	n/a	-	
Annual energy consumption store [kWh/m2/year]	225	RVO [155]	This number is assumed based on the energy label of the store.
Equipment			
Forklifts	3	Client data	
Hand pallet truck	5	Client data	
Conveyor belt	1	Client data	
Packaging			
Packaging type used by retailer	Cardboard and polybags	Client data	A product is packaged with a light polybag, next the product is packaged with either cardboard or a poly bag.

E

Environmental data

In this Appendix, the data is provided on the various sources of inputs for the environmental calculations. In the column named 'assumptions/additional comments', information is given on the scope of the EF.

Table E.1: Data for the calculation and measurement of emissions

Data description	Figures	Database/source	Assumptions/additional comments
Buildings			
Warehouse and storage facility leased (scope 3) [kgCO2e/m2]	86.344	GHG Protocol [88]	
Machinery and equipment [kgCO2e/EUR]	0.373	DEFRA [44]	
Electricity unknown [kgCO2e/kWh]	0.337	CO2emissiefactoren [31]	Well-to-wheel
Electricity renewables [kgCO2e/kWh]	0	CO2emissiefactoren [31]	Well-to-wheel
Clothing - waste treatements			
Reuse/restocking of clothing [kgCO2e/kg]	0.152	DEFRA [43]	
Landfill of clothing [kgCO2e/kg]	0.450	DEFRA [43]	Collection, transportation, and landfill emissions are included [43].
Incineration of clothing [kgCO2e/kg]	0.021	DEFRA [43]	Includes the process of incineration and generation of electricity [44].
Recycling of clothing closed loop [kgCO2e/kg]	0.021	DEFRA [43]	Including transport to a recovery facility [43].
Packaging material			
Cardboard [kgCO2e/kg]	1.53	[34]	Cradle to grave [34]
Plastic (LDPE) [kgCO2e/kg]	2.10	[139]	Cradle to raw material [139]
Plastic (HDPE) [kgCO2e/kg]	1.92	[139]	Cradle to raw material [139]
Corrugated cardboard [kgCO2e/kg]	0.94	[34]	Box with recycled material of 61.4%, cradle to grave [34].
Packaging - waste treatements			
Cardboard landfill [kgCO2e/kg]	1.042	DEFRA [43]	Including collection, transportation, and landfill emissions [43].
Cardboard incineration [kgCO2e/kg]	0.021	DEFRA [43]	Includes the process of incineration and generation of electricity [44].
Plastic average landfill [kgCO2e/kg]	0.089	DEFRA [43]	Including collection, transportation, and landfill emissions [43].
Plastic average incineration [kgCO2e/kg]	0.021	DEFRA [43]	Includes the process of incineration and generation of electricity [44].
Plastic HDPE landfill [kgCO2e/kg]	0.089	DEFRA [43]	Including collection, transportation, and landfill emissions [43].
Plastic HDPE incineration [kgCO2e/kg]	0.021	DEFRA [43]	Includes the process of incineration and generation of electricity [44].
Plastic LDPE and LLDPE landfill [kgCO2e/kg]	0.089	DEFRA [43]	Including collection, transportation, and landfill emissions [43].
Plastic LDPE and LLDPE incineration [kgCO2e/kg]	0.021	DEFRA [43]	Includes the process of incineration and generation of electricity [44].
Passenger travel			
Bike (non-electric) [kgCO2e/km]	0	CO2emissiefactoren [31]	Well-to-wheel
Walk [kgCO2e/km]	0	CO2emissiefactoren [31]	Well-to-wheel
PT (metro, bus, tram) [kgCO2e/km]	0.075	CO2emissiefactoren [31]	Well-to-wheel
Car (fuel type unknown) [kgCO2e/km]	0.193	CO2emissiefactoren [31]	Well-to-wheel
Car (petrol, medium size) [kgCO2e/km]	0.204	CO2emissiefactoren [31]	Well-to-wheel
Car (diesel, medium size) [kgCO2e/km]	0.18	CO2emissiefactoren [31]	Well-to-wheel
Car (electric, green electricity, medium size) [kgCO2e/km]	0.002	CO2emissiefactoren [31]	Well-to-wheel
Freight transport			
Truck 10-20 ton, average laden [kgCO2e/kg-km]	0.256	CO2emissiefactoren [31]	Well-to-wheel
Truck trailer diesel [kgCO2e/kg-km]	0.117	CE Delft Stream [110]	Well-to-wheel
Tractor trailer electric [kgCO2e/kg-km]	0.117	CE Delft Stream [110]	Well-to-wheel
Truck trailer light diesel [kgCO2e/kg-km]	0.260	CE Delft Stream [110]	Well-to-wheel
Truck trailer light LNG [kgCO2e/kg-km]	0.236	CE Delft Stream [110]	Well-to-wheel
Vans average diesel (up to 3.5 tonnes) [kgCO2e/kg-km]	0.579	DEFRA [43]	By transport of a 3PL, well-to-wheel
Vans average petrol (up to 3.5 tonnes) [kgCO2e/kg-km]	0.754	DEFRA [43]	By transport of a 3PL, well-to-wheel
Vans average BEV (up to 3.5 tonnes) [kgCO2e/kg-km]	0.251	DEFRA [43]	By transport of a 3PL, well-to-wheel
Vans average fuel type unknown (up to 3.5 tonnes) [kgCO2e/kg-km]	0.584	DEFRA [43]	By transport of a 3PL, well-to-wheel

F

Cost data

This appendix provides information for the calculation of the economic indicators.

Table F.1: Cost data

Data description	Figures	Database/source	Assumptions/additional comments
Retailer costs			
Warehouse lease costs [EU/m2/year]	1044	Statista [173]	This is an average value for large warehouses (area >5000 m2) at specified location.
Brick-and-mortar rental costs [EUR/m2/year]	2025	Cushman & Wakefield [38]	This is the average of the range 1600-2450 EUR/m2/year, specified for the store location.
Equipment costs			
Costs forklift [EUR/unit/year]	11328	[121]	A commonly used type of forklift is a reach truck. Price ranges from 600-1500 dollars per month. Price data of base year (2020) used for conversion of dollars to euros.
Costs conveyor belt [EUR/unit/year]	995	[1, 197]	A conveyor belt costs 1570-5060 dollars on average, assuming the belt lasts three years. The average value of this range is assumed. Price data of base year used for conversion dollar to euros.
Costs manual picker [EUR/unit/year]	2100	[13]	Price range between 4000-10000 dollar per equipment. Assumed replacement after 3 years. Price data of base year used for conversion dollar to euros.
Transport costs			
Van - average [EUR/kg-km]	0.007601	KiM [187]	Diesel fueled, includes fixed, variable, staff, mode-specific, and general operating costs.
Electric van [EU/kg-km]	0.011934	Adapted from RWS, KiM [41, 187]	Cost are assumed to be 57% higher compared to an average diesel truck
Truck trailer [EU/kg-km]	0.000166	KiM [187]	Diesel fueled truck trailer for bulk cargo, includes fixed, variable, staff, mode-specific, and general operating costs.
Electric truck trailer [EU/kg-km]	0.002606	Adapted from RWS, KiM [41, 187]	Cost are assumed to be 57% higher compared to an average diesel truck
Hydrogen truck trailer (7.5-19t) [EU/kg-km]	0.000498	Adapted from RWS, KiM [41, 187]	Cost are assumed to be three times higher compared to an average diesel truck.
Transport fee parcel at collection point [eu/parcel]	12.3-21.6	[89]	Ranges from 1-2 items to 9-10 items per returned parcel.
Labor costs			
Minimum hourly wage (Spain) [EUR/hour]	5.94	Statista [74]	Assumed a 40-hour workweek. The value is adapted to the base year.
Minimum hourly wage (Netherlands) [EUR/hour]	9.54	Rijksoverheid [156]	Assumed a 40-hour workweek. The value is adapted to the base year.
Overhead expenses (Spain) [%]	29.9	Eurodev [55]	Percent of the gross-based salary.
Overhead expenses (Netherlands) [%]	24	Eurodev [56]	Percent of the gross-based salary.
Cost of receiving a product [EUR/item]	2.25	[89]	
Cost of inspection and storage returns [EUR/item]	4.5	[89]	
Disposal costs			
Landfill charge (Spain) [EUR/tonne]	47.1	European Commission [69]	Landfill charge for base year
Incineration charge (Spain) [EUR/tonne]	23.6	European Commission [69]	Disposal charge for base year
Cardboard recycling [EUR/tonne]	104	Eurostat [73]	
Plastic recycling [EUR/tonne]	247	Eurostat [73]	
Mechanical recycling closed loop traditional [EU/kg-output]	0.7	[122]	Ranges from 500-900 euros per ton, so the average value is assumed.

G

Performance gaps

This section presents the scenarios' relative performance RP values and the performance gaps M based on the scores from section 7.3.

The relative performance RP and performance gap are calculated using the theory described in section 3.5. The relative performance expresses the ratio between the actual and target performance. So, the actual performance of a scenario in section 7.3 is divided by the target performance, which is the benchmark score on the CI. A higher value of RP illustrates a closer actual performance relative to the target performance, expressed by the benchmark.

The performance gap M represents the difference in performance between the actual and target values, calculated by subtracting the actual performance from the target performance. The best performance is achieved when the values of all indicators are minimized, so a lower value for this represents a better performance score [49]. As seen in Table G.1, the extreme variant of scenario 1 has the lowest performance gap in this table, and the extreme variant of scenario 3 is the largest.

Table G.1: Overview of relative performance and performance gap, source: (Author)

	Relative performance RP	**Performance gap M**
Benchmark	100.00%	0.00
Base case	75.58%	0.45
Scenario 1. Moderate shifting customer behavior	78.13%	0.40
Scenario 1. Extreme shifting customer behavior	85.80%	0.26
Scenario 2. Moderate green supply chain management	71.41%	0.53
Scenario 2. Extreme green supply chain management	74.95%	0.46
Scenario 3. Moderate economic attractiveness of renewables	72.99%	0.50
Scenario 3. Extreme economic attractiveness of renewables	69.91%	0.56
Scenario 4. Moderate governmental support to a circular business model	77.61%	0.41
Scenario 4. Extreme governmental support to a circular business model	77.71%	0.41
Scenario 5. Moderate technological innovations	75.33%	0.46
Scenario 5. Extreme technological innovations	80.51%	0.36

H

Uncertainty and sensitivity analysis

H.1. Rescaled pairwise comparison matrix

In subsection 7.2.5, the weights of the CI were rescaled by asking different experts. The weights presented in Table 7.4 are derived based on the pairwise comparison matrix presented in Table H.1. The data from the comparison matrix originates from a group of 3 experts. The consistency of this matrix is checked and below the threshold value of 0.10, indicating statistically consistent weights [142].

With V_1: packaging emissions, V_2: transport emissions, V_3: warehouse and equipment emissions, V_4: product recovery emissions, V_5: brick-and-mortar emissions, V_6: transport costs, V_7: warehouse and equipment costs, V_8: labor costs, V_9: recovery costs, V_{10}: brick-and-mortar costs.

Table H.1: Pairwise comparison matrix rescaled weights, source: (Author)

	V1	**V2**	**V3**	**V4**	**V5**	**V6**	**V7**	**V8**	**V9**	**V10**
V1	1	1/5	1/3	1/2	1/2	1/4	1/4	1/2	1/4	1/2
V2	5	1	5	4	5	1/2	1/2	3	2	2
V3	3	1/5	1	1/4	2	1/5	1/3	1	1/3	1
V4	2	1/4	4	1	4	1/5	1/4	1/2	1/2	1
V5	2	1/5	1/2	1/4	1	1/6	1/3	1/3	1/4	1/3
V6	4	2	5	5	6	1	2	3	1	3
V7	4	2	3	4	3	1/2	1	1/2	1	1
V8	2	1/3	1	2	3	1/3	2	1	3	2
V9	4	1/2	3	2	4	1	1	1/3	1	1/2
V10	2	1/2	1	1	3	1/3	1	1/2	2	1

H.2. Data on the sensitivity analysis

This appendix contains the data of the SA performed by changing several input variables. The following variables were changed: equipment costs, warehouse emission value, incineration costs, and landfill costs. First, the raw data is presented, followed by the aggregated values in subsection H.2.2.

H.2.1. Raw data after increasing and decreasing the variables

The following section gives the raw data for each of the values V_1: packaging emissions, V_2: transport emissions, V_3: warehouse and equipment emissions, V_4: product recovery emissions, V_5: brick-and-mortar emissions, V_6: transport costs, V_7: warehouse and equipment costs, V_8: labor costs, V_9: recovery costs, V_{10}: brick-and-mortar costs.

- Scenario 1. Shifting customer behavior
- Scenario 2. Green supply chain management
- Scenario 3. Economic attractiveness of renewables
- Scenario 4. Governmental support for circularity
- Scenario 5. Technological innovations

The equipment costs are increased by 25% in Table H.2 and decreased by 25% in Table H.3. The transport cost for electric vans is increased by 25% in Table H.4 and decreased accordingly in Table H.5. The warehouse emission value is increased by 25% in Table H.6 and decreased by 25% in Table H.7. In Table H.8, the landfill costs are increased by 25% and decreased by 25% in Table H.9. Lastly, in Table H.10, the incineration costs are increased by 25%. In Table H.11, the raw data is visible after decreasing these values by 25%.

Table H.2: Raw data after increasing the equipment costs by 25%, source: (Author)

	V1 [kgCO2e/ returned product]	**V2** [kgCO2e/ returned product]	**V3** [kgCO2e/ returned product]	**V4** [kgCO2e/ returned product]	**V5** [kgCO2e/ returned product]	**V6** [euro returned product]	**V7** [euro/ returned product]	**V8** [euro/ returned product]	**V9** [euro/ returned product]	**V10** [euro/ returned product]
Benchmark	0.0161	14.4975	0.7427	0.0080	0.4844	0.2302	12.3998	5.0962	0.4967	1.9026
Base case overall performance	0.0790	32.2167	1.0922	0.0114	0.7124	0.2302	12.3998	5.0962	0.4967	1.9026
Scenario 1. Moderate	0.0639	32.3545	1.0834	0.0107	0.7184	0.2683	11.2998	5.0891	0.4941	1.9187
Scenario 1. Extreme	0.0452	31.5089	1.0786	0.0110	0.7192	0.2272	10.2459	5.0882	0.5071	1.9207
Scenario 2. Moderate	0.0632	30.5256	0.8396	0.0103	0.5343	0.2683	14.0891	5.0962	0.5149	2.4734
Scenario 2. Extreme	0.0457	29.0887	0.5870	0.0130	0.3562	0.3068	13.3188	5.0962	0.5016	2.6636
Scenario 3. Moderate	0.0752	30.2375	0.9911	0.0109	0.6412	0.2554	13.0198	5.3510	0.5249	1.9977
Scenario 3. Extreme	0.0765	27.2687	0.8396	0.0109	0.5343	0.2892	13.6398	5.6058	0.5568	2.0929
Scenario 4. Moderate	0.0306	32.2167	0.9455	0.0099	0.6087	0.2302	13.0822	5.1007	0.5709	2.0081
Scenario 4. Extreme	0.0157	32.2167	0.7932	0.0095	0.5013	0.2302	13.3913	5.1007	0.6231	2.0559
Scenario 5. Moderate	0.0739	32.4684	1.1168	0.0118	0.7131	0.2334	12.6796	5.1159	0.5196	1.9044
Scenario 5. Extreme	0.0760	29.0975	1.0813	0.0098	0.7188	0.2314	12.2762	5.0875	0.4913	1.9196

Table H.3: Raw data after decreasing the equipment costs by 25%, source: (Author)

	V1 [kgCO2e/ returned product]	**V2** [kgCO2e/ returned product]	**V3** [kgCO2e/ returned product]	**V4** [kgCO2e/ returned product]	**V5** [kgCO2e/ returned product]	**V6** [euro returned product]	**V7** [euro/ returned product]	**V8** [euro/ returned product]	**V9** [euro/ returned product]	**V10** [euro/ returned product]
Benchmark	0.0161	14.4975	0.7427	0.0074	0.4844	0.2302	12.3589	5.0962	0.5115	1.9026
Base case overall performance	0.0748	32.2167	1.0922	0.0106	0.7124	0.2302	12.3589	5.0962	0.5115	1.9026
Scenario 1. Moderate	0.0661	32.3545	1.0834	0.0109	0.7184	0.2294	11.2592	5.0890	0.5167	1.9187
Scenario 1. Extreme	0.0512	31.5089	1.0786	0.0111	0.7192	0.2272	10.2055	5.0882	0.5324	1.9207
Scenario 2. Moderate	0.0623	30.5256	0.8396	0.0112	0.5343	0.2683	14.0481	5.0960	0.5026	2.4734
Scenario 2. Extreme	0.0455	29.0887	0.5870	0.0105	0.3562	0.3068	13.2779	5.0962	0.5102	2.6636
Scenario 3. Moderate	0.0755	30.2375	0.9911	0.0132	0.6412	0.2554	12.9768	5.3510	0.5420	1.9977
Scenario 3. Extreme	0.0766	27.2687	0.8396	0.0129	0.5343	0.2892	13.5948	5.6058	0.5335	2.0929
Scenario 4. Moderate	0.0315	32.2167	0.9460	0.0106	0.6087	0.2310	13.0411	5.1007	0.5869	2.0081
Scenario 4. Extreme	0.0162	32.2167	0.0097	0.0097	0.5013	0.2302	13.3501	5.1007	0.6132	2.0559
Scenario 5. Moderate	0.0789	32.4684	1.1168	0.0101	0.7131	0.2334	12.6378	5.1159	0.5181	1.9044
Scenario 5. Extreme	0.0786	29.0975	1.0813	0.0101	0.7188	0.2310	12.2357	5.0875	0.5109	1.9196

Table H.4: Raw data after increasing the transport cost of electric vans by 25%, source: (Author)

	V1 [kgCO2e/ returned product]	**V2** [kgCO2e/ returned product]	**V3** [kgCO2e/ returned product]	**V4** [kgCO2e/ returned product]	**V5** [kgCO2e/ returned product]	**V6** [euro returned product]	**V7** [euro/ returned product]	**V8** [euro/ returned product]	**V9** [euro/ returned product]	**V10** [euro/ returned product]
Benchmark	0.016	14.498	0.743	0.008	0.484	0.230	12.400	5.096	0.497	1.903
Base case overall performance	0.079	32.217	1.092	0.011	0.712	0.230	12.400	5.096	0.497	1.903
Scenario 1. Moderate	0.062	32.355	1.083	0.012	0.718	0.229	11.280	5.089	0.508	1.919
Scenario 1. Extreme	0.046	31.509	1.079	0.010	0.719	0.227	10.226	5.085	0.517	1.921
Scenario 2. Moderate	0.063	30.526	0.840	0.010	0.534	0.295	14.089	5.096	0.515	2.473
Scenario 2. Extreme	0.046	29.089	0.587	0.013	0.356	0.361	13.319	5.096	0.502	2.664
Scenario 3. Moderate	0.078	30.237	0.991	0.010	0.641	0.263	12.998	5.351	0.511	1.998
Scenario 3. Extreme	0.077	27.269	0.840	0.012	0.534	0.308	13.617	5.606	0.559	2.093
Scenario 4. Moderate	0.031	32.217	0.945	0.010	0.609	0.230	13.082	5.101	0.571	2.008
Scenario 4. Extreme	0.016	32.217	0.793	0.010	0.501	0.230	13.391	5.101	0.623	2.056
Scenario 5. Moderate	0.072	32.468	1.117	0.012	0.713	0.233	12.659	5.116	0.502	1.904
Scenario 5. Extreme	0.077	29.097	1.081	0.011	0.719	0.231	12.256	5.087	0.514	1.920

H.2.2. Aggregated values CI

The SA increases and decreases the equipment costs, electric van costs, warehouse emission value, incineration costs, and landfill costs by 25%. In the main text, the correlation coefficient is presented based on the outcomes of this analysis. The values of the CI are presented in Table H.12.

Table H.5: Raw data after decreasing the transport cost of electric vans by 25%, source: (Author)

	V1 [kgCO2e/ returned product]	**V2** [kgCO2e/ returned product]	**V3** [kgCO2e/ returned product]	**V4** [kgCO2e/ returned product]	**V5** [kgCO2e/ returned product]	**V6** [euro returned product]	**V7** [euro/ returned product]	**V8** [euro/ returned product]	**V9** [euro/ returned product]	**V10** [euro/ returned product]
Benchmark	0.016	14.498	0.743	0.008	0.484	0.230	12.400	5.096	0.508	1.903
Base case overall performance	0.079	32.217	1.092	0.011	0.712	0.230	12.400	5.096	0.508	1.903
Scenario 1. Moderate	0.062	32.355	1.083	0.012	0.718	0.229	11.280	5.089	0.500	1.919
Scenario 1. Extreme	0.046	31.509	1.079	0.010	0.719	0.227	10.226	5.085	0.491	1.921
Scenario 2. Moderate	0.063	30.526	0.840	0.010	0.534	0.295	14.089	5.096	0.515	2.473
Scenario 2. Extreme	0.046	29.089	0.587	0.013	0.356	0.361	13.319	5.096	0.502	2.664
Scenario 3. Moderate	0.078	30.237	0.991	0.010	0.641	0.263	12.998	5.351	0.511	1.998
Scenario 3. Extreme	0.077	27.269	0.840	0.012	0.534	0.308	13.617	5.606	0.559	2.093
Scenario 4. Moderate	0.031	32.217	0.945	0.010	0.609	0.230	13.082	5.101	0.571	2.008
Scenario 4. Extreme	0.016	32.217	0.793	0.010	0.501	0.230	13.391	5.101	0.623	2.056
Scenario 5. Moderate	0.072	32.468	1.117	0.012	0.713	0.233	12.659	5.116	0.514	1.904
Scenario 5. Extreme	0.077	29.097	1.081	0.011	0.719	0.231	12.256	5.087	0.515	1.920

Table H.6: Raw data after increasing the warehouse emissions value by 25%, source: (Author)

	V1 [kgCO2e/ returned product]	**V2** [kgCO2e/ returned product]	**V3** [kgCO2e/ returned product]	**V4** [kgCO2e/ returned product]	**V5** [kgCO2e/ returned product]	**V6** [euro returned product]	**V7** [euro/ returned product]	**V8** [euro/ returned product]	**V9** [euro/ returned product]	**V10** [euro/ returned product]
Benchmark	0.0160	14.4975	0.9144	0.0078	0.4844	0.2302	12.3793	5.0962	0.5243	1.9026
Base case overall performance	0.0724	32.2167	1.3447	0.0111	0.7124	0.2302	12.3793	5.0962	0.5243	1.9026
Scenario 1. Moderate	0.0631	32.3545	1.3339	0.0118	0.7184	0.2294	11.2795	5.0891	0.5039	1.9187
Scenario 1. Extreme	0.0483	31.5089	1.3280	0.0096	0.7192	0.2272	10.2257	5.0853	0.5328	1.9207
Scenario 2. Moderate	0.0616	30.5256	1.0290	0.0113	0.5343	0.2683	14.0686	5.0962	0.4937	2.4734
Scenario 2. Extreme	0.0457	29.0887	0.7133	0.0112	0.3562	0.3068	13.2983	5.0962	0.4835	2.6636
Scenario 3. Moderate	0.0779	30.2375	1.2184	0.0126	0.6412	0.2554	12.9768	5.3510	0.5492	1.9977
Scenario 3. Extreme	0.0767	27.2687	1.0290	0.0128	0.5343	0.2892	13.6173	5.6058	0.5374	2.0929
Scenario 4. Moderate	0.0297	32.2167	1.1613	0.0103	0.6087	0.2302	13.0617	5.1007	0.5708	2.0081
Scenario 4. Extreme	0.0159	32.2167	0.9709	0.0094	0.5013	0.2302	13.3707	5.1007	0.6260	2.0559
Scenario 5. Moderate	0.0759	32.4684	1.3751	0.0103	0.7131	0.2334	12.6587	5.1159	0.5469	1.9044
Scenario 5. Extreme	0.0787	29.0975	1.3313	0.0101	0.7188	0.2314	12.2560	5.0875	0.5102	1.9196

Table H.7: Raw data after decreasing the warehouse emissions value by 25%, source: (Author)

	V1 [kgCO2e/ returned product]	**V2** [kgCO2e/ returned product]	**V3** [kgCO2e/ returned product]	**V4** [kgCO2e/ returned product]	**V5** [kgCO2e/ returned product]	**V6** [euro returned product]	**V7** [euro/ returned product]	**V8** [euro/ returned product]	**V9** [euro/ returned product]	**V10** [euro/ returned product]
Benchmark	0.0157	14.4975	0.5709	0.0073	0.4844	0.2302	12.3793	5.0962	0.5291	1.9026
Base case overall performance	0.0762	32.2167	0.8396	0.0105	0.7124	0.2302	12.3793	5.0962	0.5291	1.9026
Scenario 1. Moderate	0.0620	32.3545	0.8328	0.0128	0.7184	0.2294	11.3791	5.0891	0.5290	1.9187
Scenario 1. Extreme	0.0463	31.5089	0.8292	0.0109	0.7192	0.2272	10.2257	5.0853	0.5110	1.9207
Scenario 2. Moderate	0.0616	30.5256	0.6502	0.0114	0.5343	0.2683	14.0686	5.0962	0.5134	2.4734
Scenario 2. Extreme	0.0465	29.0887	0.4607	0.0113	0.3562	0.3068	13.2983	5.0962	0.4887	2.6636
Scenario 3. Moderate	0.0741	30.2375	0.7638	0.0111	0.6412	0.2554	12.9768	5.3510	0.5157	1.9977
Scenario 3. Extreme	0.0800	27.2687	0.6502	0.0116	0.5343	0.2892	13.6173	5.6058	0.5584	2.0929
Scenario 4. Moderate	0.0296	32.2167	0.7297	0.0102	0.6087	0.2302	13.0617	5.1007	0.5803	2.0081
Scenario 4. Extreme	0.0156	32.2167	0.6154	0.0094	0.5013	0.2302	13.3707	5.1007	0.6224	2.0559
Scenario 5. Moderate	0.0760	32.4684	0.8585	0.0111	0.7131	0.2334	12.6587	5.1159	0.5203	1.9044
Scenario 5. Extreme	0.0782	29.0975	0.8312	0.0096	0.7188	0.2314	12.2560	5.0875	0.4979	1.9196

Table H.8: Raw data after increasing the landfill cost by 25%, source: (Author)

	V1 [kgCO2e/ returned product]	**V2** [kgCO2e/ returned product]	**V3** [kgCO2e/ returned product]	**V4** [kgCO2e/ returned product]	**V5** [kgCO2e/ returned product]	**V6** [euro returned product]	**V7** [euro/ returned product]	**V8** [euro/ returned product]	**V9** [euro/ returned product]	**V10** [euro/ returned product]
Benchmark	0.0161	14.4975	0.7427	0.0071	0.4844	0.2302	12.3793	5.0962	0.5121	1.9026
Base case overall performance	0.0765	32.2167	1.0922	0.0102	0.7124	0.2302	12.3793	5.0962	0.5121	1.9026
Scenario 1. Moderate	0.0613	32.3545	1.0834	0.0121	0.7184	0.2294	11.2795	5.0891	0.5032	1.9187
Scenario 1. Extreme	0.0478	31.5089	1.0786	0.0108	0.7192	0.2272	10.2257	5.0853	0.5045	1.9207
Scenario 2. Moderate	0.0610	30.5256	0.8396	0.0132	0.5343	0.2683	14.0686	5.0962	0.5048	2.4734
Scenario 2. Extreme	0.0474	29.0887	0.5870	0.0115	0.3562	0.3068	13.2983	5.0962	0.5186	2.6636
Scenario 3. Moderate	0.0750	30.2375	0.9911	0.0114	0.6412	0.2554	12.9768	5.3510	0.5354	1.9977
Scenario 3. Extreme	0.0799	27.2687	0.8396	0.0122	0.5343	0.2892	13.6173	5.6058	0.5379	2.0929
Scenario 4. Moderate	0.0282	32.2167	0.9455	0.0099	0.6087	0.2302	13.0617	5.1007	0.5834	2.0081
Scenario 4. Extreme	0.0156	32.2167	0.7932	0.0095	0.5013	0.2302	13.3707	5.1007	0.6254	2.0559
Scenario 5. Moderate	0.0759	32.4684	1.1168	0.0100	0.7131	0.2334	12.6587	5.1159	0.5019	1.9044
Scenario 5. Extreme	0.0753	29.0975	1.0813	0.0095	0.7188	0.2314	12.2560	5.0875	0.4884	1.9196

Table H.9: Raw data after decreasing the landfill cost by 25%, source: (Author)

	V1 [kgCO2e/ returned product]	**V2** [kgCO2e/ returned product]	**V3** [kgCO2e/ returned product]	**V4** [kgCO2e/ returned product]	**V5** [kgCO2e/ returned product]	**V6** [euro returned product]	**V7** [euro/ returned product]	**V8** [euro/ returned product]	**V9** [euro/ returned product]	**V10** [euro/ returned product]
Benchmark	0.0161	14.4975	0.7427	0.0071	0.4844	0.2302	12.3793	5.0962	0.4743	1.9026
Base case overall performance	0.0765	32.2167	1.0922	0.0102	0.7124	0.2302	12.3793	5.0962	0.4743	1.9026
Scenario 1. Moderate	0.0613	32.3545	1.0834	0.0121	0.7184	0.2294	11.2795	5.0891	0.4695	1.9187
Scenario 1. Extreme	0.0478	31.5089	1.0786	0.0108	0.7192	0.2272	10.2257	5.0853	0.4761	1.9207
Scenario 2. Moderate	0.0610	30.5256	0.8396	0.0132	0.5343	0.2683	14.0686	5.0962	0.4832	2.4734
Scenario 2. Extreme	0.0474	29.0887	0.5870	0.0115	0.3562	0.3068	13.2983	5.0962	0.5145	2.6636
Scenario 3. Moderate	0.0750	30.2375	0.9911	0.0114	0.6412	0.2554	12.9768	5.3510	0.5293	1.9977
Scenario 3. Extreme	0.0799	27.2687	0.8396	0.0122	0.5343	0.2892	13.6173	5.6058	0.5560	2.0929
Scenario 4. Moderate	0.0282	32.2167	0.9455	0.0099	0.6087	0.2302	13.0617	5.1007	0.5648	2.0081
Scenario 4. Extreme	0.0156	32.2167	0.7932	0.0095	0.5013	0.2302	13.3707	5.1007	0.6051	2.0559
Scenario 5. Moderate	0.0759	32.4684	1.1168	0.0100	0.7131	0.2334	12.6587	5.1159	0.5187	1.9044
Scenario 5. Extreme	0.0753	29.0975	1.0813	0.0095	0.7188	0.2314	12.2560	5.0875	0.5135	1.9196

Table H.10: Raw data after increasing the incineration cost by 25%, source: (Author)

	V1 [kgCO2e/ returned product]	**V2** [kgCO2e/ returned product]	**V3** [kgCO2e/ returned product]	**V4** [kgCO2e/ returned product]	**V5** [kgCO2e/ returned product]	**V6** [euro returned product]	**V7** [euro/ returned product]	**V8** [euro/ returned product]	**V9** [euro/ returned product]	**V10** [euro/ returned product]
Benchmark	0.0159	14.4975	0.7427	0.0076	0.4844	0.2302	12.3793	5.0962	0.5060	1.9026
Base case overall performance	0.0753	32.2167	1.0922	0.0108	0.7124	0.2302	12.3793	5.0962	0.5060	1.9026
Scenario 1. Moderate	0.0646	32.3545	1.0834	0.0123	0.7184	0.2294	11.2795	5.0891	0.5046	1.9187
Scenario 1. Extreme	0.0455	31.5089	1.0786	0.0114	0.7192	0.2272	10.2257	5.0853	0.5193	1.9207
Scenario 2. Moderate	0.0617	30.5256	0.8396	0.0111	0.5343	0.2683	14.0686	5.0962	0.5036	2.4734
Scenario 2. Extreme	0.0454	29.0887	0.5870	0.0107	0.3562	0.3068	13.2983	5.0962	0.5177	2.6636
Scenario 3. Moderate	0.0753	30.2375	0.9911	0.0120	0.6412	0.2554	12.9768	5.3510	0.5228	1.9977
Scenario 3. Extreme	0.0754	27.2687	0.8396	0.0114	0.5343	0.2892	13.6173	5.6058	0.5348	2.0929
Scenario 4. Moderate	0.0301	32.2167	0.9455	0.0099	0.6087	0.2302	13.0617	5.1007	0.5745	2.0081
Scenario 4. Extreme	0.0157	32.2167	0.7932	0.0095	0.5013	0.2302	13.3707	5.1007	0.6229	2.0559
Scenario 5. Moderate	0.0778	32.4684	1.1168	0.0101	0.7131	0.2334	12.6587	5.1159	0.5346	1.9044
Scenario 5. Extreme	0.0750	29.0975	1.0813	0.0097	0.7188	0.2314	12.2560	5.0875	0.5062	1.9196

Table H.11: Raw data after decreasing the incineration cost by 25%, source: (Author)

	V1 [kgCO2e/ returned product]	**V2** [kgCO2e/ returned product]	**V3** [kgCO2e/ returned product]	**V4** [kgCO2e/ returned product]	**V5** [kgCO2e/ returned product]	**V6** [euro returned product]	**V7** [euro/ returned product]	**V8** [euro/ returned product]	**V9** [euro/ returned product]	**V10** [euro/ returned product]
Benchmark	0.0161	14.4975	0.7427	0.0081	0.4844	0.2302	12.3793	5.0962	0.4969	1.9026
Base case overall performance	0.0810	32.2167	1.0922	0.0116	0.7124	0.2302	12.3793	5.0962	0.4969	1.9026
Scenario 1. Moderate	0.0626	32.3545	1.0834	0.0126	0.7184	0.2294	11.2795	5.0891	0.5034	1.9187
Scenario 1. Extreme	0.0494	31.5089	1.0786	0.0107	0.7192	0.2272	10.2257	5.0853	0.5206	1.9207
Scenario 2. Moderate	0.0599	30.5256	0.8396	0.0118	0.5343	0.2683	14.0686	5.0962	0.4983	2.4734
Scenario 2. Extreme	0.0460	29.0887	0.5870	0.0112	0.3562	0.3068	13.2983	5.0962	0.5028	2.6636
Scenario 3. Moderate	0.0763	30.2375	0.9911	0.0108	0.6412	0.2554	12.9983	5.3510	0.5645	1.9977
Scenario 3. Extreme	0.0749	27.2687	0.8396	0.0125	0.5343	0.2892	13.6173	5.6058	0.5577	2.0929
Scenario 4. Moderate	0.0290	32.2167	0.9455	0.0117	0.6087	0.2302	13.0617	5.1007	0.5710	2.0081
Scenario 4. Extreme	0.0154	32.2167	0.7932	0.0095	0.5013	0.2302	13.3707	5.1007	0.6175	2.0559
Scenario 5. Moderate	0.0787	32.4684	1.1168	0.0100	0.7131	0.2334	12.6587	5.1159	0.5108	1.9044
Scenario 5. Extreme	0.0754	29.0975	1.0813	0.0100	0.7188	0.2314	12.2560	5.0875	0.5048	1.9196

Table H.12: Aggregated scores CI after performing the sensitivity analysis, source: (Author)

	Equipment costs + 25%	**Equipment cost - 25%**	**Transport cost electric van + 25%**	**Transport cost electric van -25%**	**Warehouse emission value +25%**	**Warehouse emission value -25%**	**Incineration cost +25%**	**Incineration cost -25%**	**Landfill cost +25%**	**Landfill cost -25%**
Benchmark	1.857	1.809	1.863	1.841	1.819	1.820	1.837	1.858	1.860	1.862
Base case	1.386	1.392	1.389	1.371	1.374	1.376	1.390	1.394	1.389	1.381
Scenario 1. Moderate	1.412	1.450	1.442	1.457	1.442	1.411	1.444	1.438	1.433	1.434
Scenario 1. Extreme	1.535	1.513	1.544	1.544	1.529	1.527	1.533	1.532	1.519	1.528
Scenario 2. Moderate	1.325	1.299	1.328	1.348	1.319	1.309	1.296	1.321	1.321	1.317
Scenario 2. Extreme	1.363	1.353	1.365	1.426	1.391	1.388	1.373	1.365	1.384	1.388
Scenario 3. Moderate	1.343	1.295	1.368	1.342	1.301	1.344	1.331	1.328	1.327	1.318
Scenario 3. Extreme	1.267	1.238	1.282	1.225	1.250	1.252	1.261	1.244	1.271	1.246
Scenario 4. Moderate	1.406	1.365	1.407	1.405	1.399	1.389	1.392	1.398	1.398	1.382
Scenario 4. Extreme	1.438	1.468	1.439	1.438	1.435	1.432	1.432	1.420	1.431	1.436
Scenario 5. Moderate	1.342	1.360	1.361	1.352	1.336	1.343	1.365	1.356	1.345	1.366
Scenario 5. Extreme	1.451	1.434	1.431	1.437	1.430	1.442	1.451	1.426	1.444	1.446

I
Scenario analysis

This appendix gives an in-depth overview of the performance of the different scenarios with the benchmark. A radar chart does this. The indicators are defined on the spokes of the radar. For each indicator, better performance is obtained when the value is higher, corresponding to values more on the outside of the axis in the radar. Values closer to the center are less preferred in terms of performance. V_1: packaging emissions, V_2: transport emissions, V_3: warehouse and equipment emissions, V_4: product recovery emissions, V_5: brick-and-mortar emissions, V_6: transport costs, V_7: warehouse and equipment costs, V_8: labor costs, V_9: recovery costs, V_{10}: brick-and-mortar costs.

- Scenario 1. Shifting customer behavior
- Scenario 2. Green supply chain management
- Scenario 3. Economic attractiveness of renewables
- Scenario 4. Governmental support for circularity
- Scenario 5. Technological innovations

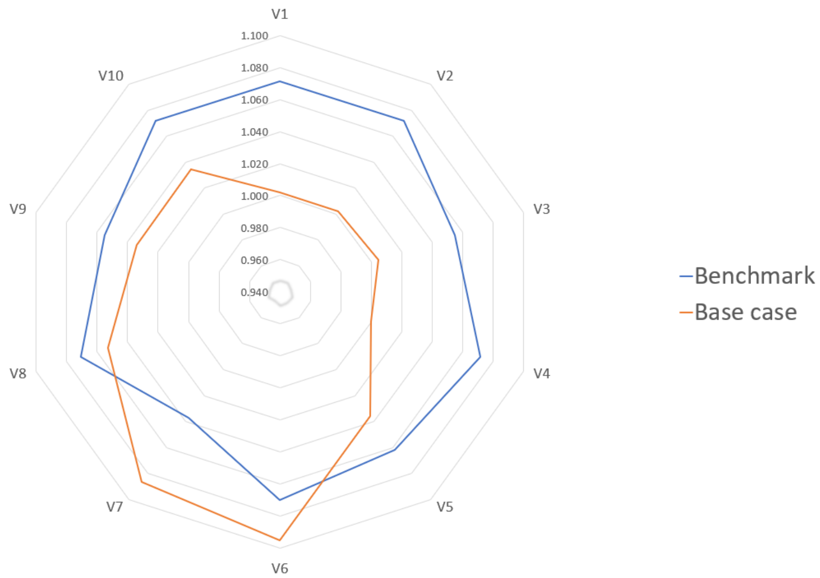

Figure I.1: Radar chart benchmark and base case performance, source: (Author)

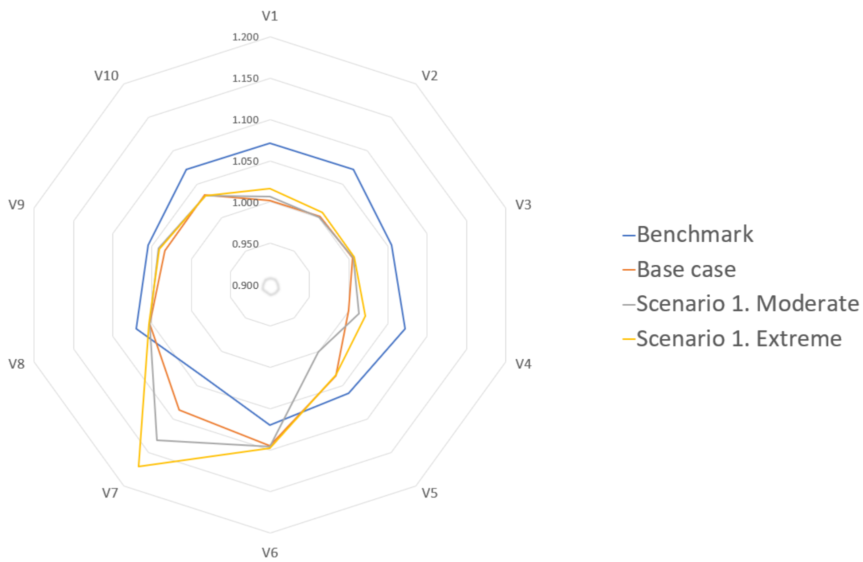

Figure I.2: Radar chart benchmark and scenario 1, source: (Author)

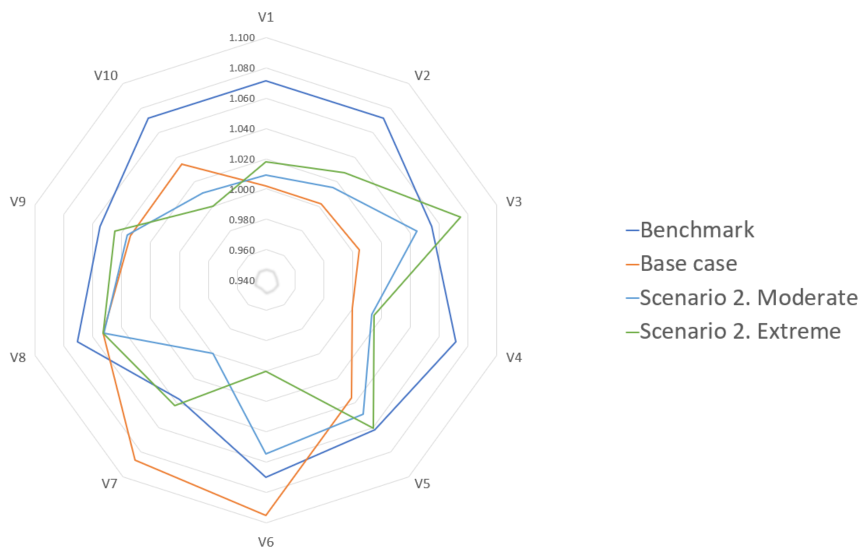

Figure I.3: Radar chart benchmark and scenario 2, source: (Author)

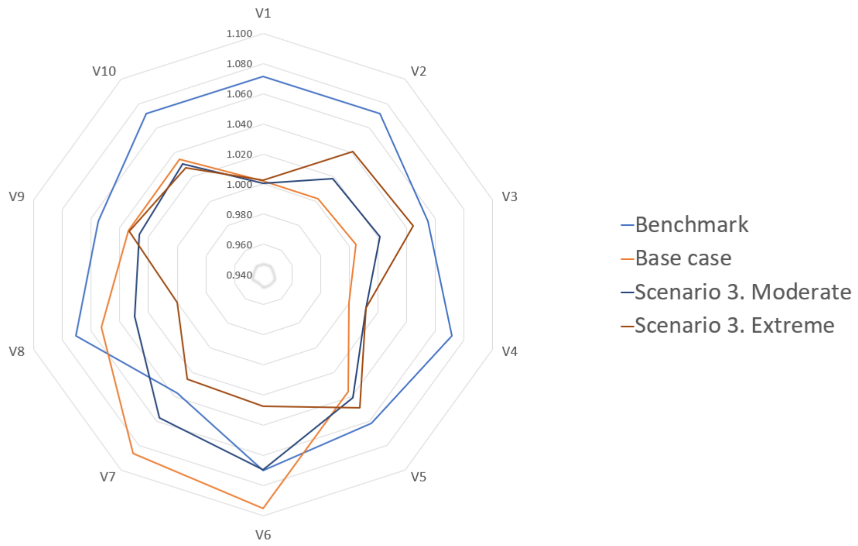

Figure I.4: Radar chart benchmark and scenario 3, source: (Author)

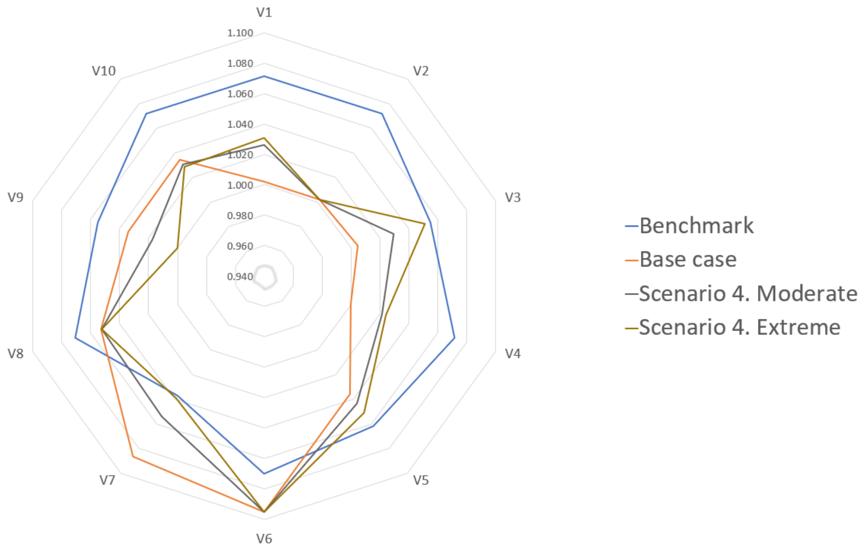

Figure I.5: Radar chart benchmark and scenario 4, source: (Author)

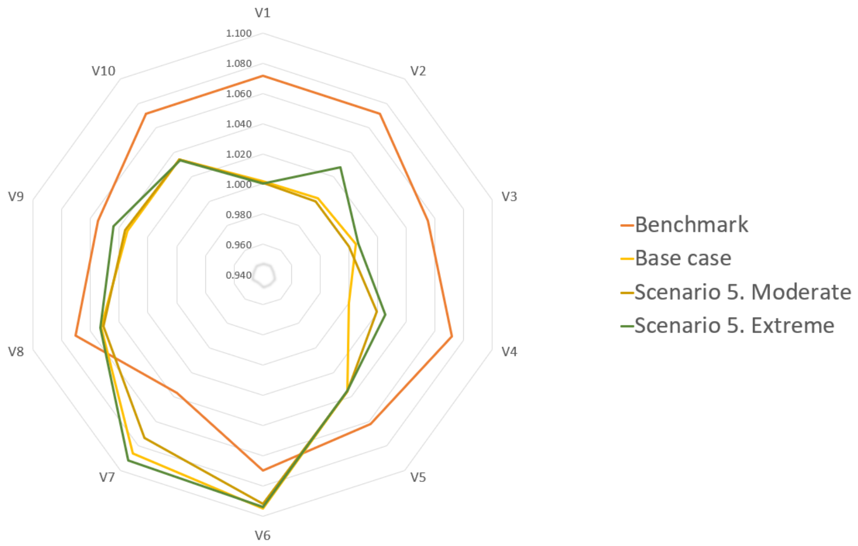

Figure I.6: Radar chart benchmark and scenario 5, source: (Author)