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Sustainable Industrial Packaging

Elevating Supply Chain Circularity and Business Competitiveness

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Sustainable Industrial Packaging

Elevating Supply Chain Circularity and Business Competitiveness

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Elevating Supply Chain Circularity and Business Competitiveness

Nathalie Silva

LUND UNIVERSITY

DOCTORAL DISSERTATION

Doctoral dissertation for the degree of Doctor of Philosophy (PhD) at the Faculty of Engineering at Lund University to be publicly defended on the 4th of October of 2024 at 09.15 at Stora Hörsalen, Department of Design Sciences (IKDC), Sölvegatan 26, Lund

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Abstract:

Industrial packaging plays an important role in the performance and environmental efficiency of supply chains. Despite it being so important, the implications that industrial packaging decisions have on the logistics operations (and vice-versa) are not completely understood. This thesis contributes to the understanding of the impacts of sustainable industrial packaging by discussing the importance of integrating such decisions within the supply chain context. This research also explores the opportunities that can emerge from sustainability-oriented innovations on packaging logistics and how these innovations can increase business competitiveness.

The research presented in this thesis is reported in the five attached research articles, the findings of which are built on each other. The first paper frames and sets the boundaries of the thesis and is a stepping stone to the articles that follow. The other four papers delve into two research streams. Each of the streams corresponds to the two research questions (RQs) to which this thesis contributes. The first research stream focuses on the key aspects that should be considered when planning and implementing sustainable industrial packaging initiatives. The second stream focuses on the implementation of sustainability-oriented innovations on packaging logistics to increase efficiency and business competitiveness.

The five papers applied different methodologies, some using qualitative and some quantitative data. The first paper (Paper I) presents a systematic literature review. Two papers (Papers II and IV) follow with two case studies: the former using the life-cycle assessment (LCA) methodology, and the latter applying a design science approach. The remaining papers (Papers III and V) build on the findings from the case studies; the former explore other impact indicators to better grasp the impacts of plastic pollution to complement the global warming potential (GWP) analysis (research stream 1). The latter proposes a set of opportunities to test on packaging logistics in home deliveries of food and groceries to help differentiate the business model and lead to a competitive edge (research stream 2).

The findings from this research have relevance for researchers, practitioners and policymakers. First, the emphasis on the importance of considering the supply chain context: for example, the impact of the transport modes or the location to which the packaging will be shipped (and thus turned into waste) can cause significant effects, oftentimes overlooked in the packaging development phase. This also has implications for the policies, since some regulations focus on steering companies in certain directions, others that dismiss the context in which the changes are applied. Second, the importance of adjusting processes and practices when transitioning from linear to circular business models. Viable transitions to circular models require a thorough analysis. This includes the change in dynamics and perceptions of the different actors actively involved in all stages of the process. This is particularly complex when the final customer (consumer) is one of them, as their reasoning and intrinsic motivations are different from those discussed and negotiated with other business partners.

Key words: Circular economy, Competitiveness, Industrial packaging, Logistics, Sustainability, Supply chain.

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Sustainable Industrial Packaging

Elevating Supply Chain Circularity and Business Competitiveness

Nathalie Silva

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"I don't know. We have everything we need to be happy, but we aren't happy. Something is missing. I looked around. The only thing I positively knew was gone was the books I'd burned in ten or twelve years. So I thought books might help."

Ray Bradbury, Fahrenheit 451, 1953

To Mom and Dad, and my brothers.

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Abstract

Industrial packaging plays an important role in the performance and environmental efficiency of supply chains. Despite it being so important, the implications that industrial packaging decisions have on the logistics operations (and vice-versa) are not completely understood. This thesis contributes to the understanding of the impacts of sustainable industrial packaging by discussing the importance of integrating such decisions within the supply chain context. This research also explores the opportunities that can emerge from sustainability-oriented innovations on packaging logistics and how these innovations can increase business competitiveness.

The research presented in this thesis is reported in the five attached research articles, the findings of which are built on each other. The first paper frames and sets the boundaries of the thesis and is a stepping stone to the articles that follow. The other four papers delve into two research streams. Each of the streams corresponds to the two research questions (RQs) to which this thesis contributes. The first research stream focuses on the key aspects that should be considered when planning and implementing sustainable industrial packaging initiatives. The second stream focuses on the implementation of sustainability-oriented innovations on packaging logistics to increase efficiency and business competitiveness.

The five papers applied different methodologies, some using qualitative and some quantitative data. The first paper (Paper I) presents a systematic literature review. Two papers (Papers II and IV) follow with two case studies: the former using the life-cycle assessment (LCA) methodology, and the latter applying a design science approach. The remaining papers (Papers III and V) build on the findings from the case studies; the former explore other impact indicators to better grasp the impacts of plastic pollution to complement the global warming potential (GWP) analysis (research stream 1). The latter proposes a set of opportunities to test on packaging logistics in home deliveries of food and groceries to help differentiate the business model and lead to a competitive edge (research stream 2).

The findings from this research have relevance for researchers, practitioners and policymakers. First, the emphasis on the importance of considering the supply chain context: for example, the impact of the transport modes or the location to which the packaging will be shipped (and thus turned into waste) can cause significant effects, oftentimes overlooked in the packaging development phase. This also has implications for the policies, since some regulations focus on steering companies in certain directions, others that dismiss the context in which the changes are applied. Second, the importance of adjusting processes and practices when transitioning from linear to circular business models. Viable transitions to circular models require a thorough analysis. This includes the change in dynamics and perceptions of the

different actors actively involved in all stages of the process. This is particularly complex when the final customer (consumer) is one of them, as their reasoning and intrinsic motivations are different from those discussed and negotiated with other business partners.

Popular Science summary

Statistics show that packaging waste has been escalating worldwide. In 2020, almost 80 million tons of packaging waste were produced in Europe alone. Two of the main reasons for this trend are high patterns of consumption and increasingly more well-established global supply chains. In this research it is explored different ways to implement sustainable packaging solutions by reducing the emissions and waste generated in the manufacturing, usage, and end-of-life phases.

Nowadays, virtually everything we buy comes with packaging. Packaging is necessary mostly because it provides protection, handleability and unitisation. Without packaging more products would get damaged and become waste before being used or consumed. A commonly discussed example is cucumbers that are often wrapped in plastic. The plastic film can be perceived as unnecessary; however, it protects cucumbers from losing water, which increases shelf life and reduces the risk of becoming waste.

Even though packaging is necessary, for the most part, it becomes a real problem when it turns into waste. Recent legislation and restrictions are increasing the awareness of the real consequences of waste by trying to push countries to reduce the waste they produce. Nonetheless, some developed countries are still shipping containers of waste daily to be handled in poorer countries, particularly in Asia. That waste often ends up in open dumps or burn pits. Both fates have dramatic, negative consequences on the environment, for example, pollution of the soil and water streams. Burning waste also causes the release of unfiltered toxic gases to the atmosphere, which is a serious threat to human life and the surrounding environment. Despite the obvious consequences of mishandling waste, there are less obvious ones that are also problematic when throwing out waste. For example, studies have found that plastic debris can reach the oceans even when dumped 50 km away from the coast. That is because, with time, plastics break down into small pieces, such as mesoplastics (between 0.5 to 5cm), microplastics (<5mm) and nanoplastics (<1 μm) making them light enough to be transported by wind and tides.

For decades, companies have been designing and developing their businesses and supply chains to be as cost effective as possible. This has led most businesses to run on linear supply chains. In other words, most products (packaging inclusive) are designed to follow the “take, make, waste” model.

Policymakers, industrial practitioners and researchers are joining forces to drive changes to viably implement strategies that can extend the lifespan of the packaging with different R-strategies for a circular economy (Reuse, Repair, Refurbish, Remanufacture, Repurpose) and reduce the impact at the end-of-life (Recycle). However, most of the R’s – and particularly the ones to extend the lifespan – require organised reverse logistics to have packaging shipped back.

With global supply chains being the norm rather than the exception, the distances to return packaging to where it came from can magnify the quantity of greenhouse gas emissions from transport. This is the case if the returning process is not carefully strategised and implemented.

The different dimensions of environmentally sustainable decisions generate dilemmas. One dilemma that industry is facing nowadays is between waste and emissions: saving one aspect often means sacrificing the other. In general terms, disposable packaging creates more waste, but the shifting to reusable packaging may exacerbate global warming from burning fossil fuel for the "extra" transport and other logistics activities. Finding a solution that weighs both dimensions (waste and emissions) requires a strong analysis between the packaging solution (e.g., size, weight, material) and the logistics system (e.g., transport modes, distances). Ensuring that the company does not end up shifting the environmental burden is crucial to avoid the often-seen phenomenon of greenwashing.

One trend that has been developing in recent years is e-commerce. The need (or desire) for the convenience of having things delivered at our doorstep has been expanding to a vast number of sectors. While some advocate that it allows the reduction of emissions – because a few vehicles replace the trips of multiple private cars to the retailers – some uphold that these services are only exacerbating the problem.

E-tailers (online retailers) are starting to develop strategies and implement sustainable practices in their services. Regarding packaging, e-tailers are starting to abandon plastics and testing more sustainable and recyclable materials. However, the ambition for more sustainable packaging is dependent on the willingness of customers to primarily collaborate. This is because it is the end customer/ consumer who decides if the packaging is tossed away, thrown into the unsorted bin, or sorted and placed in the proper recycling bin.

Nonetheless, the fact that this last stretch connects customers at a relatively close range makes it a setting with great potential to apply reusable packaging. In these settings, for example, the emissions from the reverse logistics are substantially lower than the average distances in business-to-business settings. This means that the compromise between reducing waste and increasing emissions is less than when applied in long (global) supply chains.

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When I started my PhD life, I could have not predicted the twists and turns that the next five and a half years had reserved for me. This pursuit for knowledge turned out to be not only a journey of academic development, but also of personal growth.

First and foremost, my deepest gratitude to my supervisors: Professor Fredrik Nilsson, Dr. Katrin Molina-Besch and Professor Annika Olsson. The support I got from you during these years is immeasurable. I will always be grateful that you trusted my work that my concerns were always met with good advice and understanding. Thank you Fredrik, for the discussions about my research and progress and that you always had a positive attitude and mindset. Thank you for the freedom you allowed me and for the curiosity you enticed me with. Thank you Katrin, for your strong ethics and for always being open and keen to sharing your knowledge and expertise. Thank you for your kindness and endless selflessness. Thank you, Annika, for your wisdom and genuine care. A true inspiration!

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A big thank you to my family: Mom, Dad, and my brothers, for all the support and encouragement all the way through. Thank you for raising me in a home where honesty, humbleness and perseverance are everyday values.

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A final note to the randomness of life and to all the people I have crossed paths with along the way, and who, in one way or another, shaped my personality and sharpened my way of thinking. Cheers!

Lund, August 2024

Nathalie Silva

List of papers and authors' contribution

Paper I

Silva, N., & Pålsson, H. (2022). Industrial packaging and its impact on sustainability and circular economy: A systematic literature review. *Journal of Cleaner Production*, Vol. 333. https://doi.org/10.1016/j.jclepro.2021.130165

The paper systematically reviews the literature on industrial packaging. The analysis categorises the existing literature and explores the relationship of that sample with respect to sustainability and circular economy.

Nathalie Silva was the main contributor to this study, collected, classified and analysed the data. She was also responsible for writing the manuscript submitted to the journal and for rewriting and editing in the review process. Henrik Pålsson contributed with guidance in the design and methodology, and continuous supervision and feedback that lead to significant improvements in the paper. He also contributed to the editing during the review process. The first version of this paper was presented at the 32nd NOFOMA 2020, in Reykjavik, Iceland.

Paper II

Silva, N., & Molina-Besch, K. (2023). Replacing plastic with corrugated cardboard: A carbon footprint analysis of disposable packaging in a B2B global supply chain – A case study. *Resources, Conservation and Recycling,* Vol. 191. https://doi.org/10.1016/j.resconrec.2023.106871

This paper is based on a case study in collaboration with an information and communication technologies (ICT) company. It is based on life-cycle assessment (LCA) that was conducted to compare the environmental implications from shifting a packaging cushioning packaging to one with fibre-based cushioning. The study also explores how that shift is impacted by the supply chain and logistics contexts.

Nathalie Silva was responsible for the conceptualisation, methodology, formal analysis and writing and editing. Katrin Molina-Besch made a significant contribution with her expertise in the conceptualisation, methodology, data curation, writing and editing, as well as ongoing supervision and guidance.

Paper III

Silva, N. (to be submitted). Do LCAs encourage landfilling of plastic waste? Testing and proposing LCA impact indicators to complement GWP analysis.

This paper builds on the findings from Paper II and challenges the suitability of the global warming potential (GWP) in LCAs when comparing plastic with biodegradable materials. It proposes complementing the analyses with impact indicators that can more accurately measure the impact of plastics in nature. The case study is used to show that with these impact indicators, the results can be significantly different than those based on GWP and lead to contradictory decisions.

Nathalie Silva is the solo author and was responsible for the conceptualization of the paper, analyses and writing and editing of the manuscript.

Paper IV

Silva, N., & Nilsson, F. (under review). Exploring the circular last mile: Reusable packaging in home delivery of food and groceries using a design science approach

This paper is based on a design science approach that was used to develop a circular packaging logistics artefact for home deliveries of food and groceries. This artefact was tested on four deliveries using a sample of 8 customers. Their feedback was collected along with the feedback from the other actors impacted by the new set-up (delivery drivers, warehouse staff, management board). The authors used it to discuss the theoretical, managerial and policy implications. This paper is currently under a third review.

Nathalie Silva took the lead on this paper, analysed and synthesised the data from interviews and wrote most of the manuscript. Fredrik Nilsson also contributed to writing and editing the text and took the lead in multiple rounds of revisions and discussion between the authors. Both authors were actively involved in the field-test, the development of the interview protocols and the analysis of the data.

Paper V

Silva, N., & Nilsson, F. (under review). Sustainable packaging logistics innovations in home delivery: Enabling competitive advantages for retail actors based on Resource-Advantage theory

This paper discussed the key learning from the case study (**Paper IV**) and the findings from a structured literature review on recent research on home deliveries of food and groceries. The articles sampled were structured and revealed underexplored potential from packaging logistics innovations that can be used as a differentiator and be turned into a competitive edge in the market. This study uses the Resource-Advantage Theory to ground the concepts of "value creation", "resource consumption" and "market advantage".

Nathalie Silva was responsible for the methodology section and formal analysis as well as writing and editing. Fredrik Nilsson also contributed with writing and reviewing as well as leading the discussions. Both were responsible for the conceptualisation of the paper which was developed in ongoing dialogue.

Abbreviations

B2B	Business-to-Business
B2C	Business-to-Customer
EOL	End-of-life
LCA	Life-Cycle Assessment
GHG	Greenhouse gases
GWP	Global Warming Potential
RQ	Research Question
SLR	Systematic Literature Review

1. Introduction

This chapter first presents the research background that brings forward the overall context of this thesis and some important definitions and key concepts (1.1). This is followed by the research problematisation (1.2), purpose and research questions (1.3), and the research focus and demarcations (1.4). Finally, the thesis outline is presented (1.5).

1.1. Background

Society is progressing in a way that is compromising "(…) its ability to meet the essential needs of its people in the future – by overexploiting resources, for example" (World Commission on Environment and Development, 1987, Ch. 2). Even though this point was raised several decades ago, it is attracting more concern now than ever before. To ensure a sustainable growth, governmental institutions and public policies play a crucial role by setting the bar and steering industry towards green transformation strategies (Cheba et al., 2022). The stricter control, regulations, and taxes, make this movement towards environmental sustainability less and less of a voluntary and optional act and more of a mandatory and legal requirement.

The corporate vision should be that the sustainability commitment transcends the boundaries within the firm, expanding the vision farther and integrating sustainable practices with the actors involved in the supply chain. A supply chain is a "network of organisations that are involved, through upstream and downstream linkages, (…) that produce value in the form of products and services in the hands of the ultimate consumer" (Mangan & Lalwani, 2016, p. 10). This tallies with the idea that supply chain management is about joint planning and shared information to make supply chains more efficient and competitive (Albino et al., 2002). Even though the focus of supply chain management for many decades was cost efficiency, the efforts to reduce their environmental footprint and to make better use of resources has been expanding in recent years, and somehow still competing with costs in the decision processes of the corporate world.

Now, and with the implementation of sustainable goals, these networks are not aiming solely to "*produce value*" but also do it in a way in which the consumption of resources is planned and optimised. Processes and activities are adjusted with the "integration of economic, environmental, and social considerations (…) to efficiently and effectively manage the material, information, and capital flows associated with the procurement, production, and distribution of products or services" (Ahi & Searcy, 2013, p. 390).

Growing concerns about sustainability are changing how enterprises develop their business ideas (Barros et al., 2021) and select their supply chain partners (Osei et al., 2023). This is why sustainable awareness is crucial for competitiveness in the current business world: a company can leverage its market advantage by minimizing resource consumption, optimizing operations, and enhancing its sustainability reputation (Carter et al., 2021). Besides the positive impact on the customers' perceptions, companies that show higher commitment to sustainable practices also tend to attract more interest to initiate or maintain business (Seuring & Müller, 2008). The current market trends – high demand of goods, requests for express deliveries, overseas shipments, multi-modal transport, and e-commerce fast deliveries – increase the vulnerability for risks and inhibit the opportunities to implement more sustainable practices.

Environmental policies set the guidelines on how businesses should measure and evaluate their environmental performance. Nevertheless, in the last two decades, the packaging policies have become less effective and are not able to contradict the consumption trends (Rouw & Worrell, 2011). The concept of circular packaging, for example, emerges from the 'concern about the quantity of waste headed for landfill sites and the depletion of natural resources' (Bell, 2021, p. 370). However, and despite the overall pressure and efforts to reduce packaging, it is estimated that up until 2026 the growth of packaging materials consumption will be 4% per year (Smithers, 2021).

1.2. Research problem

Businesses have been developed around cost-efficiency. Thus, operations and supply chains were designed to optimise that dimension, often increased complexity in the value chain (e.g. extra shipments and/or outsourced services with cheaper labour). The effort to minimising costs has led firms to seek for cheaper ways to supply their demands. This means that there has been a tendency for supply chains to become more global and therefore highly dependent on efficient transport and other logistics operations. Long distances and multi-modal transport (which require extra handling) make products more vulnerable to damage and therefore, constrain

the possibility of reducing the use of packaging. From a circular economy perspective, the characteristics of global supply chains are also averse to its implementation: some of the main reasons are complex reverse logistics, extra coordination, supply chain risks and organisational and/or market resistance.

For that reason, and despite the stricter and stricter environmental policies and the (more recent) businesses' ambition to reduce their environmental footprint of their supply chains, it is still a great challenge to implement green strategies and to make them compatible with the way businesses are designed and built to operate. This means that to adjust and become more sustainable, a business may have to restructure its operations. This can increase costs and reduce profits, but in the long term may increase the business's viability and competitiveness.

In addition to the global supply chains challenges, the more recent business trend of e-commerce and the focus on last-mile deliveries have resulted in an increase of individual shipments (Escudero-Santana et al., 2022). This leads to more packaging again. For different reasons than those in global supply chains, this market segment can also be challenging to adopt and implement certain green practices such as reverse logistics. Examples of this are the low margins (that are commonly used in these services) (McKinsey, 2021), the risk of lowering the customers' experience, the fact that delivery points are scattered and other "product specific" challenges. The last of these challenges is particularly relevant in the context of food, as food quality and food safety are absolute priorities and cannot be questioned. These challenges together with the fact that the value of implementing reverse logistics does not add value that can overshadow the risks restrain businesses from considering reverse logistics (and particularly the use of circular packaging) in their business models.

Environmental policies are designed to steer companies to make certain decisions without encouraging them to integrate these decisions with other processes and activities. As a result, companies often disregard the overlaps between them. When packaging decisions are taken without considering the effects on logistics activities and vice-versa, there is a high chance that the solutions will be sub-optimised (Pålsson & Hellström, 2016). On a similar note, when it comes to decisions to reduce the environmental impacts, packaging is often taken out of the context, and the real extension of the consequences is not entirely assessed (Silva & Pålsson, 2022). This can cause negative consequences in different processes upstream or downstream of the supply chain.

Integrating packaging logistics requires an ample understanding of the direct and indirect impacts of packaging and logistics sustainable performance. Industry faces a difficult challenge as there are multiple (and complex) perspectives that need to be optimised concurrently. Combining the requirements that the product asks for,

with a solution that minimises the environmental impact while keeping costs low is as difficult as it is critical.

While there is a growing body of research exploring sustainable packaging, the intricacies of packaging logistics are still lack of research. To avoid inaccurate decisions, it is of importance to understand how the logistics and supply chain contexts affect sustainable packaging decisions, if not addressed properly, this can potentially, cause more harm than good.

1.3. Purpose and research questions

Sustainability is a term that encompasses multiple dimensions and can, therefore, be judged from multiple perspectives. This complexity makes it difficult for businesses to make clear-cut decisions regarding sustainable packaging logistics solutions. Some of the dimensions that draw the most attention are waste produced, resources consumed, emissions released, and the amount of plastic used. There are also indirect impacts that each decision implies in logistics activities and supply chain structures, which can offset the benefits and thus need to be analysed and accounted for. Knowing that it is challenging to optimise all the environmental dimensions, the overall sustainability can also be affected by the requirements of the product that the packaging is designed to contain (e.g., food) and the context in which it is applied (i.e., supply chain). This complexity can result in trade-offs that cause companies to face dilemmas (Molina-Besch, 2018; Prendeville et al., 2017).

Industrial packaging is a core concept in the thesis, and it refers to transport packaging and distribution packaging (Casell, 2011) (the concept is further explained in Chapter 2. Frame of reference).

This research focuses on industrial packaging and how the supply chain context in which it is applied influences and constrains the sustainability decisions. The research presented analyses three distinct supply chain contexts: (1) the impact of distances travelled, and transport modes used in the movement of goods, through the study of global supply chains vs. local supply chains; (2) the challenges from the business context (B2B vs. B2C); and (3) the metrics by which packaging options and logistics are measured and assessed (GWP vs. ecotoxicity). From there, and to support the importance of sustainable packaging logistics, the aim of the research was to build on the premise that sustainability-oriented innovations in packaging logistics can reveal opportunities to add value and to be used as a competitive advantage in the market.

The purpose of the research presented in this thesis is to contribute knowledge on **the environmental impacts and opportunities from sustainable industrial packaging**. The aims to answer the following two Research Questions (RQs).

> ***RQ1:*** *What key aspects should be considered when planning and implementing sustainable industrial packaging initiatives?*
>
> ***RQ2:*** *What are the challenges of implementing circular industrial packaging solutions in B2C settings and how to turn them into efficiency and competitiveness?*

The RQs are addressed the following way. The first one (RQ1) explores the impact of industrial packaging on the environment and the risk that some strategies might transfer to other processes of the life cycle of the packaging (e.g., EOL) or to logistics activities (e.g., transport). The second one (RQ2) explores the potential of adopting more sustainable and circular packaging logistics solutions to increase business competitiveness.

1.4. Research focus and demarcations

Packaging is generally categorised based on three levels: primary, secondary, and tertiary (Hellström & Saghir, 2007). Primary packaging is in direct contact with the product. Besides protection, the primary packaging level is often used as a marketing tool and is designed to attract attention from the customer. Secondary packaging contains several primary packaging units, and its main function is to facilitate the movement and handling of several units at the same time. Tertiary packaging is the level that assembles multiple secondary packaging units (Pålsson, 2018).

Packaging can also be categorised based on a different terminology: industrial or consumer packaging. Industrial packaging (also called transport packaging or distribution packaging) is used for the transport, storage, and handling of goods. The emphasis of this type of packaging is on "protection, functional performance and shipping considerations" (Verghese & Lewis, 2007). As per definition, industrial packaging is not the only packaging connecting B2B settings, since it is also used to facilitate transport and distribution of goods, and thus, can be relevant in B2C contexts as well. Primary packaging is typically considered "consumer packaging", and secondary and tertiary packaging "industrial packaging", but this is not always the case. For example, primary packaging (in direct contact with the product) that is also the transport packaging can be considered industrial packaging, as in the **Paper II** case study.

As mentioned before, this research focuses on the relationship between sustainable industrial packaging practices and the supply chain context. In this thesis, the analysis is conducted from the perspective of global supply chains B2B, and last-mile deliveries B2C. While industrial packaging is predominantly relevant in the context of B2B, and because of that, it has been extensively researched. The same cannot be said for the B2C context, as in this context the focus is primarily the consumer packaging. With the growth in popularity of e-commerce, industrial packaging (transport packaging) becomes relevant to the discussion on sustainability and efficient deliveries. However, research is somehow behind in that stream. The overlap between industrial packaging and the final consumer is one of the streams this research aims to contribute to: explore the intricacies of industrial packaging meeting up with the final customer, and how e-commerce may be a prospective setting in which to implement circular industrial packaging.

Packaging design and development is not included in the scope of this thesis, even though some of the findings presented and discussed are relevant to those phases and should be considered in the early stages of the definition of the packaging solutions.

1.5. Thesis outline

This thesis is structured as following. This introduction chapter is followed by the frame of reference (Chapter 2), where the boundaries of the thesis are defined. Chapter 3 presents the methodology in which the theoretical stance of this research is discussed. Chapter 4 presents a summary of the appended papers. Chapter 5 states how the research results answer the two RQs in Section 1.3. In Chapter 6 the findings are discussed in relation to relevant current research. Chapter 7 is the last and presents some concluding remarks in which the author draws the final considerations and the contributions of the research as well as limitations and future research opportunities.

2. Frame of reference

This chapter provides an overview of the topics and theories that are most relevant to the theoretical formation of this research. A theoretical map is also presented to frame the thesis and to support the reader in understanding how the adopted concepts relate to each other.

2.1. Positioning of the research

A point at the core of this research is the fact that packaging (and particularly industrial packaging) should not be studied detached from the supply chain conditions. Thus, the supply chain management discipline is relevant for the positioning of this thesis and to the points discussed. Supply chain management sets the scene and delineates the opportunities and limitations that are encountered when a business is defining their packaging strategies (Pålsson & Sandberg, 2022). For example, packaging procurement can limit the options when deciding the packaging materials, because some materials can be unavailable or too expensive in certain areas of the globe. Even though, procurement is not a central aspect in this thesis, it is used here as an example on how supply chain management can constrain the options for packaging selection. In the case study analysed in **Paper II**, it is mentioned that the company faced limited availability of EPP plastic and because of that they had to opt for a different material (EPE plastic) in some of their manufacturing plants. Opting for EPP plastic in all manufacturing plants would have resulted in significantly increased production costs.

Within supply chain management, logistics encompasses important activities and plays a pivotal role in the definition of sustainable actions. For that reason, this thesis delves, especially, into the logistics aspects and the overlaps with industrial packaging (Figure 1).

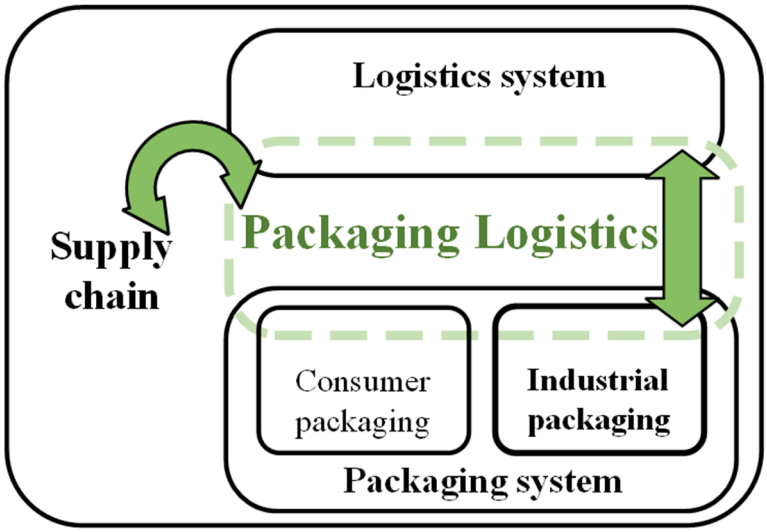

Figure 1.
Representation of the overlaps between packaging and logistics and the relationship between packaging logistics and supply chain. The packaging system is represented as consumer packaging and industrial packaging, with the latter being the focus of this thesis (adapted from **Paper IV**).

Another area this thesis touches upon is circular business model innovations and value creation in the downstream of the supply chains (Bocken & Konietzko, 2022). This relates to the opportunities that can emerge when implementing circular packaging solutions and should be explored. However, these opportunities still are somehow disregarded by e-tailers or at least not considered as a possibility to differentiate from the competition and grow to have bigger shares of the market.

Even though offering a good product and service is necessary to be a competitive and relevant business, it is also true that the efforts to implement sustainable practices contribute to a stronger positioning in the market (Bjørgen et al., 2021). The difficulty of implementing more efficient and sustainable systems magnifies the potential of every step towards that goal, and thus, the importance of capabilities to drive competitiveness (Deloitte, 2021).

2.2. Packaging logistics

The concept of packaging logistics emerges from the overlaps between packaging and the logistics systems. To ensure robust decision-making, both systems need to be considered simultaneously when taking decisions regarding packaging. Saghir (2002, p. 45) brings forward that notion in the definition of packaging logistics:

> The process of planning, implementing and controlling the coordinated packaging system of preparing goods for safe, secure, efficient and effective handling, transport, distribution, storage, retailing, consumption and recovery, reuse or disposal and related information combined with maximising consumer value, sales and hence profit.

The concept of packaging logistics raises multiple environmental trade-offs: some of them include resources' consumption (material, energy, fuel, water), emissions, and waste produced. The difficulty of addressing these dimensions concurrently, allied with the trade-offs that emerge between the environmental and economic pillars are challenging for companies to deal with and identify the most efficient strategies for sustainable growth.

Besides the fact that packaging reduces the risk of damaged products, it facilitates transport and handling, and enables the identification of product orders and customers (Lockamy III, 1995). Packaging also affects the environmental performance of transport (Meng et al., 2023). To ensure efficiency in those packaging domains, supply chains need to be well structured and needs to consider a systems' view to ensure that the "environmental and commercial costs are reduced, and efficiencies optimised for the chain as a whole" (Verghese & Lewis, 2007). Thus, the interactions between the activities within logistics systems (such as transport and warehousing) and industrial packaging ask for pondered and conscious decisions in the development phase of the packaging, particularly during the packaging design, material selection, and production phases.

2.3. Sustainable packaging and circular economy

As mentioned before, the sustainability performance of packaging can be approached from different dimensions and one well discussed example is by replacing disposable (one-way) packaging with circular packaging to reduce resource consumption and waste. Circular economy is a concept that promotes the use of resources in a more sustainable way and is based on three strategies with different circularity potentials: (1) reducing the resources consumed (narrowing flows), strategy with the highest circularity potential, (2) extending the value of the product and reusing the same product and material (slowing loops), and (3) extracting the most value out of the material through recycling or recovery of energy after combustion (closing loops), strategy with the lowest circularity potential (Bocken et al., 2016; Kirchherr et al., 2017). The concept of circular economy is built on the terms reduce, reuse, and recycle of products and materials (De Angelis et al., 2018), and is defined by Kirchherr et al. (2023, p. 7) as:

> … a regenerative economic system which necessitates a paradigm shift to replace the 'end of life' concept with reducing, alternatively reusing, recycling, and recovering materials throughout the supply chain, with the aim to promote value maintenance and sustainable development, creating environmental quality, economic development, and social equity, to benefit of current and future generations.

Even though circular economy and sustainability are concepts that go hand in hand and overlap in significant ways, they differ in some respects. For example, both see the system design and innovations as the main drivers towards the goals, and both acknowledge the importance of diversification when defining the strategies for value creation and the criticality of cooperation between stakeholders (Geissdoerfer et al., 2017). On the other hand, the two diverge in some respects, particularly that sustainability's motivation is unclear, and the goals are more open-ended, whereas circular economy defends the idea of using resources in a more efficient way and "ideally eliminating all resource input into and leakage out of the system" (Geissdoerfer et al., 2017). The fact that circular economy and sustainability can point in different directions (e.g., implementing a system with reusable materials can increase emissions) can lead to some indecisions. Therefore, businesses need a plan of action when deciding their goals and strategies to reduce the environmental impacts as well as their positioning in the market (Floyd et al., 2024).

While research on sustainability and circular economy has been expanding in the last decade (Bradley & Corsini, 2023), there is still an evident lack of understanding on how to operationalise such concepts in the industrial context. The challenges faced with sustainable and circular packaging illustrate well that idea: the theoretical knowledge is limited and lack of detailed and clearer guidelines to support companies to fully grasp the consequences of implementing sustainable and circular practices.

The context in which industrial packaging is used has a great influence on the decisions for circularity. For that reason, the supply chain cannot be disregarded when defining the (sustainable and circular) industrial packaging strategies. The implications of such decisions for the efficiency of supply chains elevate the importance of communication between supply chain partners to ensure that "environmental and commercial costs are reduced, and efficiencies optimised for the chain as a whole" (Verghese & Lewis, 2007).

Reusable products often require more robust production and/or a design and use of materials that allow for repairing, refurbishing or remanufacturing (Kirchherr et al., 2017). This can result in a perverse effect: reusable packaging can lead to an increase on the amount of material and, in situations where the number of loops is not high enough, risks increase the amount of waste produced or result in a reduction

of transport efficiency (from the increase of packaging volume and/or weight) (Koskela et al., 2014).

In general terms, B2B and B2C supply chains have different characteristics. Some of these characteristics facilitate the implementation of certain sustainable packaging logistics strategies, while others hinder them. In typical B2B settings, long distances (and all the costs, risks and uncertainties from them) are a big hurdle to the implementation of circular packaging. In B2C settings, however, distances are (typically) not a concern; one of the main challenges lies on the fact that the final consumer is partaking in the concept of returning the packaging (Pfoser et al., 2022). Due to that (and with the possibility to define and agree through signed contracts settings where both parties agree to assist and allocate resources to ensure the viability), short distanced B2B settings can have great potential. This means, not only to have efficient and effective (reverse) logistics, but it also strengthens the business relationships and communication as well as aligning and adjusting priorities in relatively short time frames (Morgado, 2008).

Besides the structured directives for industry to become greener, circular economy also aligns with some of the foundations of lean manufacturing. It is estimated that 4-10% of the manufacturers' annual turnover is spent on the management of the waste of their materials, which is a direct consequence of the 'make-use-dispose' model that is prevalent in industry (Okorie et al., 2023). Circularity can then bring an economical/financial benefit for companies from reducing the resource consumption and the production of waste (Lim et al., 2022).

2.4. Sustainable resource consumption and business competitiveness

The corporative world has grown increasingly concerned with environmental issues. While this shift is still, to a great extent, a consequence of the acknowledgement of companies of their social responsibility, the subject is becoming more controlled, regulated and taxed. Regulatory agencies and governments are not the only actors pressuring for environmental sustainability, with customers and stakeholders taking on that role too. Two strategies have been identified in the literature (Seuring & Müller, 2008) that trigger environmental and social behaviour in supply chains. The first is "supplier management for risks and performance" where the lack of commitment to sustainable practices leads to a loss of reputation and thus less interest by other entities to initiate or maintain business. The second, "supply chain management for sustainable products" relates to the customers' perception of the product's level of sustainability, which translates into trust and market advantage.

This thesis explores the concept that the consumption of resources always has negative impacts to the environment. An example, regarding packaging, is that different materials impact the environment in different ways. Plastics have positive and negative aspects, fibre-based materials have others, but neither of them is optimal (null). The fact that the context in which the packaging materials are sourced/manufactured or managed after turning into waste, as well as the impacts of the supply chain operations during the *use* phase. All of them are impacted by the decisions taken during the design phase of the packaging. All in all, resources need to be used in a more sustainable way and implementing circular packaging can be an efficient way for that transition to greener businesses, yet they need to be defined conscientiously and in close co-ordination with the supply chain and logistics operations.

There are a few theories that connect the concepts of resources, adaptability and competitiveness. Resource-Advantage Theory and Resource-Based Theory are two of the most relevant ones. The main distinction between these two theories is that the latter sees the "strategic resources" as being controlled and/or owned by the firm, while the former specifies that it is the effective and efficient deployment of "strategic resources inputs" that is the factor that gives the firms competitive advantage in the market (Varadarajan, 2023). Another factor that distinguishes the two theories is that Resource-Based Theory defends that the market is stable and therefore does not change over time. Resource-Advantage Theory, on the other hand, states that the market is dynamic and that firms consist of "heterogeneous, imperfectly mobile resources" and need constant adjustments to adapt (Hunt, 2010). Based on these reasons, this thesis relies on the Resource-Advantage Theory concepts even though it is acknowledged that Resource-Based Theory is important in the construction of market innovation and in building market advantage.

Businesses develop different dynamic capabilities to turn the organisation into being more competitive and sustainable. These dynamic capabilities, as defined by Kortus & Gutmann (2023) are "specific skills, processes, and organizational activities – that enable firms to simultaneously pursue business objectives and environmental requirements during product development cycles". This allows them to adapt quickly to volatile and fast-moving markets (Denrell & Powell, 2016). These capabilities represent the competence to strategise the resources deployed and consumed as inputs to the business. Packaging is an important dimension of businesses, and therefore, strategic decisions need to be made to optimise the tangible and intangible resources associated with it.

3. Methodology

This chapter presents the methodological stance of the research. It explains the epistemological research approach and the reasoning (deductive, inductive, and abductive) of the five papers included in the thesis (3.1). Then the research process (3.2), design (3.3), and quality (3.4) are discussed.

3.1. Research approach

3.1.1. Philosophy of science

The research presented in this thesis is constructed with a postpositivist stance. Postpositivism (or Neopositivism) is a philosophical perspective that accepts that it is not possible to reach objective and certain knowledge, and that the development of valuable insights result in the progress of understanding the world. Building on previous knowledge is what brings us closer to a full understanding of the phenomenon. In other words, the epistemological stance is that the knowledge generated in this thesis is provisional rather than absolute. The difficulties lie on the limitations of human knowledge (and subjective perspectives), but also on the context, and that it is difficult to fully grasp all the relevant dimensions (Maksimović & Evtimov, 2023).

What distinguishes postpositivism from positivism is that positivism upholds that there is one absolute truth of knowledge, whereas postpositivism acknowledges the impact of the context (Creswell, 2003; Tanlaka et al., 2019). Postpositivism seeks for "warranted assertability", which presupposes that investigation is the means to arriving at well-grounded knowledge, and that a process should not be impacted by our individual needs (Silva & Efken, 2020). This assertability is "supported by objective evidence" and by "credible, coherent and consensual" arguments (Letourneau & Allen, 1999). Postpositivism is, therefore, based on a deterministic philosophy: effects are preceded or determined by a cause or set of causes. The understanding of those causes and the relationship between them and the effects (through observations and/or measurements) is what allows knowledge creation (Creswell, 2003).

All in all, this research is another step towards a more complete understanding of the concept of sustainable industrial packaging and its intricacies. The research in the thesis was developed from this point of view: previous knowledge on sustainable packaging supports the development of new research ideas and research questions, and this is how knowledge progresses. That is how it contributes to filling the existing research gaps and at the same time unveil new ones for future research.

Even though postpositivism is sometimes assumed to be interchangeable with critical realism, their epistemological approaches are different. Critical realism defends that the understanding of social contexts and their mechanisms are "limited and subjective" (Ellaway et al., 2020). And even though critical realism shares with postpositivism that causal explanations can be measured, and that the methodological and epistemological pluralisms help a researcher closer to the reality (Patomäki & Wight, 2000), critical realism maintains that the measurements should be based on "unobservable structures" as opposed to the "empirical regularities" maintained in postpositivism (Cruickshank, 2012).

Postpositivism recognises that reality is captured imperfectly but can be "probabilistically apprehended" (Alvesson & Kärreman, 2007) and produce generalisable results (Lincoln & Guba, 2000). This applies to all five research papers, as none of them can completely represent reality but "probabilistically" encapsulate it well enough to produce knowledge that is relevant in other contexts. For example, **Paper II**, shows that the selection of the packaging material can result in negative effects on the logistics system. The paper does not argue that reality is fully represented in the model, yet it aims to discuss the possible consequences of certain packaging decisions for the logistics system and vice-versa. Another example in **Paper IV** in which it is shown that moving to circular packaging logistics solutions with (arguably) minimal adjustments – unveils challenges in logistics, and that building on previously defined operations may not be sufficient for viable solutions.

Despite the fact there are limitations in all five studies, they can be relevant in multiple contexts and should be seen as "building blocks" adding to an "edifice of knowledge" through generalisation (Lincoln & Guba, 2000). The findings from the research presented are "building blocks", since the findings from the papers feed the ones that follow. **Paper I** gathers the existing research (state of the art) on industrial packaging, structures it in research streams and explores its relationship with sustainability and circular economy. The thesis then diverges in two different streams. One research stream (starting with **Paper II**) delves into the environmental impact of packaging and the importance of considering the supply chain context to assess the direct and indirect impacts of packaging selection. It also delves into and the implications they have on the different phases of the packaging life cycle and on the logistics activities. This study inspired **Paper III**, which challenges the use of

GWP (measured by CO_2-eq. emissions) in measuring the environmental impact of plastics and identifies other available impact indicators that should be included in LCA studies. It argues that this is particularly critical when comparing plastic packaging with biodegradable materials packaging. The second research stream (starting with **Paper IV**) delves into the importance of integrating the logistics aspects and the supply chain actors when implementing circular packaging. **Paper V** emerged from what was learnt from **Paper IV** and builds on the findings from a structured literature review and Resource-Advantage Theory and puts forward a set of propositions in which e-tailers can integrate packaging and logistics to create competitive advantage for e-tail actors.

With this stance, the research results aim to present evidence and arguments built, not only, on well recognised, validated, and accepted methodologies, but also on methodologies (and methods) that fit the RQs posed in each of the papers. Despite that, and even though research methods were conducted in a sound way and the research findings are based on strong evidence, it is accepted that the "truth" is not attainable. To help overcome the limitations of singular methods, the thesis presents different perspectives and methods. This multi-method approach is defined as "critical multiplism", a postpositivist methodology in which it is understood that knowledge emerges from the "diverse engagement and interpretation of data" (Tanlaka et al., 2019).

Critical multiplism

Critical multiplism is a meta-theoretical framework that has emerged to dispute that there is no "perfect", approach and that the limitations of applying one single approach introduces theoretical and methodological biases. This framework defends that a set of approaches (methodologies or theories) can attenuate the drawbacks, or at least make them more obvious and acknowledgeable so they can be dealt with and perhaps rule them out (Patry, 2005). Critical multiplism defends that "strengths and weaknesses of different justifiable options" should be selected to "complement each other's limitations" (Houts et al., 1986). As mentioned above when discussing postpositivism, the research methods used in the papers have limitations and drawbacks. By applying critical multiplism to this research it means that those limitations are acknowledged – particularly in **Papers II** and **IV** – and that **Papers III** and **V** emerge to (1) recognise them and (2) dispute the results in a constructive manner.

Even though the research that is referred to by Houts et al. (1986) alludes to the following challenges to the "social sciences constructs", it is possible to make the parallelism of these difficulties and those found in sustainability:

- **"Ambiguities of concept description"** – Which result from the lack of consensus on how to clearly define the concepts and their boundaries. On

the other hand, the operational representation (to define the measurement or assessment of that term) needs to be agreed upon for the empirical science to be possible. The flawed "translation" between concept and operational representations leads to the two next difficulties. Making the parallelism with environmental sustainability – even though the concept of environmental sustainability is well defined, widely recognised and accepted – the operations construct of it (i.e., how to measure/assess) is not straight forward nor consensual.

- **"Operational specification inevitably includes substantive and methodological components (e.g., method variance) not in the conceptual description"** – The limitations on translating the conceptual description of sustainability to the methodological components can result in a mismatch. On top of that, the way data are collected also causes ambiguity (e.g., different methodologies, different timeframes, different metrics).

- **"Operations fail to include some components that are part of substantive description"** – Similarly to the previous point, the difficulty to translating the theorical concept into practical measurements results in overlooking some dimensions that may not be straightforward or easy to measure. The environmental sustainability is often interpreted through the lenses of GWP, even though there are many other dimensions to it. Looking from the economic pillar, it is also normal to boil it down to the impact on costs. This is because it can be rather difficult to predict the impact of a change on the profits if that change results in a market advantage (as discussed in **Paper IV**).

- **"Constructs are multidimensional, and the weights assigned to dimensions may correspond imperfectly with the weights in a conceptual description"** – Which dimensions are given more emphasis, and the reasons why they are not always obvious when moving from conceptual to operations constructs. Different dimensions of environmental sustainability can create multiple trade-offs, which then, call for the definition of priorities (based on the dimensions or the extension of the effects). GWP and CO_2-eq. emissions are one of the most widely used metrics to assess the environmental impacts, which often results in the disregard of other dimensions, which can be problematic when they show opposite findings (as shown in **Papers II** and **V**).

The literature says that critical multiplism can be applied with different strategies (Cook, 1985; Houts et al., 1986; Letourneau & Allen, 1999). In this research, several strategies of critical multiplism were applied, particularly by: (1) considering multiple stakeholders when developing the research ideas, (2) the design of the

articles that aim to address different issues within a single case study, (3) use of complex models with multiple variables, (4) analysing different contexts and measuring different metrics, and (5) considering multiple frameworks to interpret the results.

3.1.2. Scientific reasoning

To increase knowledge and contribute with new findings, one can approach the existing knowledge in different ways. There are three approaches on how knowledge is built: deductive, inductive, and abductive. Deductive reasoning is the most common approach. It refers to the process of moving from a particular theoretical consideration or set of considerations related to a certain domain and deduce a hypothesis (or several hypotheses) that must be scrutinised through empirical studies (Bryman, 2012). Inductive reasoning is the opposite of deductive reasoning: based on empirical findings and the understanding of causal relationships, the researcher generalises the knowledge into a theoretical frame (Bryman, 2012; Kovács & Spens, 2005). Abductive reasoning looks for the most likely conclusions from a set of observations. This means interpretating or re-contextualising the phenomena to understand something in a new way (Danermark et al., 2001; Kovács & Spens, 2005). **Paper I** follows a deductive reasoning, **Papers II** and **IV** follow an inductive reasoning, and **Papers III** and **V** follow an abductive reasoning.

3.2. Research process

The research process started with a scoping study to gain an overview of the existing literature, the volume of papers, and the types of studies. From there it was possible to define the protocol of the SLR (**Paper I**). This includes the boundaries, the RQs, the search string, exclusion criteria, and the methodology for data collection and analysis. The findings revealed some research opportunities that appeared no to have been sufficiently explored. From there, the inspiration for two studies (**Papers II** and **IV**) emerged. The findings from these two papers inspired the ideas for **Papers III** and **IV**, respectively. The methodologies of all the papers (**Papers I** to **V**) were revised and discussed between the authors. The analyses of the data were also adjusted during the process of developing the studies. The timeline of the studies is presented in Figure 2.

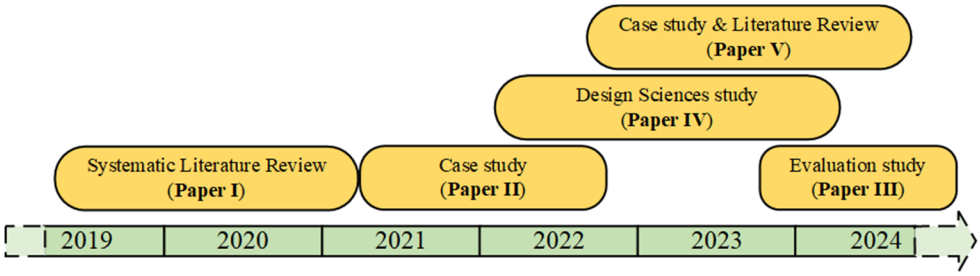

Figure 2.
Timeline of the studies.

3.3. Research design

The papers presented in this thesis – and their contributions – were not defined to be like that from the beginning. It was in the ongoing process that the research opportunities were revealed. In **Paper I**, the SLR, a set of research streams (categories and subcategories) helped in revealing a set of research gaps. These gaps disclosed two research opportunities that were considered when defining **Papers II** and **IV**. From **Paper II** the suitability of the approach commonly used was challenged for the assessing of plastic waste in nature (ditched in nature: open dumps or landfills). This resulted in **Paper III** in which it was proposed other metrics to be included in LCAs and that could measure that impact more accurately. **Paper IV**, on the other hand, revealed the negative impact from the lack of structure when designing sustainable packaging logistics innovations. Because it interferes with the current way of performing the logistics activities, it calls for a more structured way of examining and allocating the resources that should not be overlooked, which originated in **Paper V**.

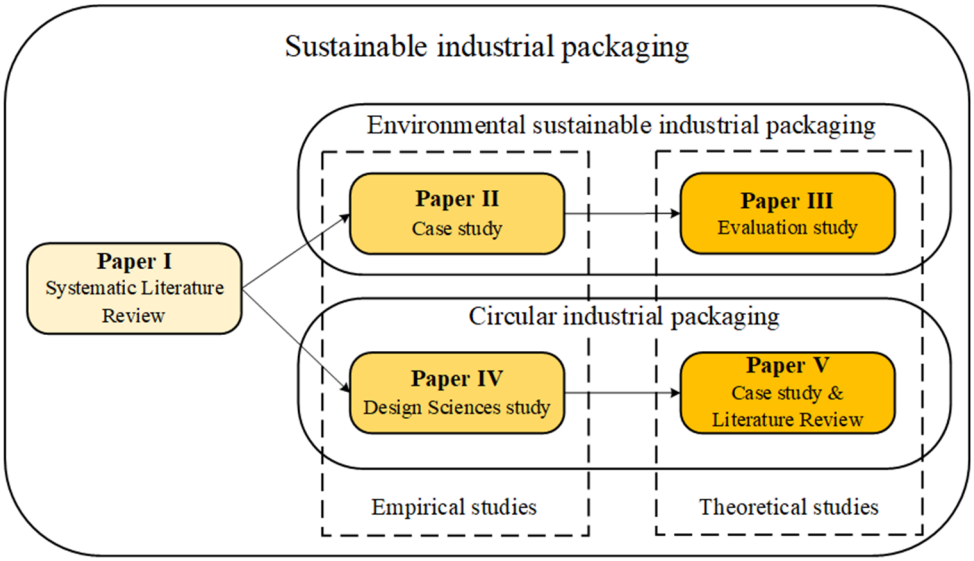

Figure 3.
Representation of the two research streams: environmental sustainability industrial packaging and circular industrial packaging. It shows how the papers build on each other.

The papers follow two different research streams (Figure 3), both originating from the findings of the SLR (**Paper I**). The aims of the first research stream (**Papers II** and **III**) were to contribute to the understanding of the environmental impacts of sustainable industrial packaging and the aspects that should be considered when defining the packaging solutions (RQ1). The aim of the second research stream (**Papers IV** and **V**) was to explore how innovations in circular packaging logistics solutions could enhance business efficiency and competitiveness in the market (RQ2). Table 1 shows the overview of the appended papers.

Table 1.
Overview of appended papers.

	Paper I	Paper II	Paper III	Paper IV	Paper V
Research design	Systematic literature review	Case study	Evaluation study	Design science study	Case study & literature review
Purpose	▪Categorise literature ▪Explore the relationship to sustainable and circular economy dimensions	▪Understand how plastic-free packaging and adding weight of packaging can influence its environmental impact in global SCs	▪Propose including other impact indicators that better assess the impact of plastics in nature and promote circularity	▪Test the viability of a reusable fibre-based packaging in home deliveries of food and groceries	▪Propose sustainable innovations on packaging logistics to increase businesses' competitiveness in home deliveries of food and groceries
Data Collection	Research articles	Research articles, database contents & company data	Research articles, database contents & company data	Field-test, semi-structured interviews & observations	Empirical studies & research articles
Research approach	Deductive research	Inductive research	Abductive research	Inductive research	Abductive research
Data	Qualitative (secondary)	Quantitative (secondary)	Quantitative (secondary)	Qualitative (primary)	Qualitative (primary & secondary)
Analysis	Meta-analysis	Life-cycle analysis	Life-cycle analysis	Artefact development and testing, observations & transcripts	Case study analysis & meta-analysis
SC context	N/A	Global	N/A	Local	Local
Context	N/A	B2B	N/A	B2C	B2C

3.3.1. Paper I

Paper I presents a SLR conducted in 2019 using the *Web of Science* database. It follows the guidelines defined by Tranfield et al. (2003). The search focused on industrial packaging and then analysed the sample from sustainability and circular economy dimensions. Discussions between the authors aimed to reach consensus on the relevant terminology, key terms to use, and the definition of the exclusion criteria. After the final sample was reached, the articles were read thoroughly and sorted based on the central focus of each study. Categories and subcategories emerged from the process. Definitions and boundaries of the categories and

subcategories required adjustments. The placement of some of the papers also required adjustments. Both adjustments were done in an iterative process. The categories were the basis of the analysis and the proposing of research opportunities that were analysed from the perspectives of environmental and circular economy.

3.3.2. Paper II

Paper II is based on a case study from a company that is moving to plastic-free packaging. The case study tested the replacement of two current packaging solutions with plastic cushioning (one with EPE and the other with EPP) with a fibre-based cushioning alternative. For the analysis, a model was developed in Excel to carry out an LCA and analyse the CO_2-eq. impacts from that shift to plastic-free packaging. Data about the packaging solutions (e.g. manufacturing processes) and the related data on the supply chain (e.g., volumes, shipments, transport modes) were collected by the company. The packaging supplier was involved to discuss technical aspects of the packaging manufacturing process. To feed the model, two other sources of data were required: (1) a database (Ecoinvent® v.3.8 [latest version at the time]) with the datasets for the activities and processes encompassed in the boundaries of this study, and (2) research articles and reports with data on how the different regions of the world manage the packaging materials after turned into waste. The methodology used for the analysis was GWP (100a) based on IPCC 2013 (Pachauri et al., 2014). The analysis was conducted using as unit of analysis the number of shipments of that product for a full year (2020). To complement the CO_2-eq. analysis, four additional metrics were applied in the model: Terrestrial Ecotoxicity, Human Toxicity, Marine Ecotoxicity, Fossil Depletion.

3.3.3. Paper III

Paper III builds on the premise that GWP (measured by CO_2-eq. emissions) is not the fairest way to measure the impact of plastics in nature and that it can be misleading, particularly when comparing it to biodegradable materials. The methodology used in this study relied largely to the model developed for **Paper II**. The datasets used in this study were, however, from the latest available version of the Ecoinvent® database [v.3.10]). To enable comparison, in a fair way, of the different impact indicators (measured by different metrics), results were normalised and given same weight (no priorities) – a standard procedure when analysing different impact indicators.

3.3.4. Paper IV

Paper IV is based on a design science (a problem-solving based methodology) study that aimed to reduce the environmental impact of home deliveries of food and groceries through the implementation of circular packaging and the use of non-refrigerated e-vans as opposed to fossil-based refrigerated trucks. The core of this methodology is exploratory-based research, but it can also delve into the explanatory and theoretical implications (Theoretical Science) (Holmström et al., 2009).
The exploratory part of the research has two phases: solution incubation, followed by solution refinement. The former phase aims to design the initial solution, and the latter phase aims to refine the solution to solve the problem. Solution incubation and solution refinement involved several actors. This was done to ensure that relevant perspectives were considered for the development of the solution. The explanatory part of this methodology also includes two phases in which the theory is developed from the previous explorative phases.

After the solution was finalised, the field-test was conducted in a real-life context. Four rounds of deliveries in the Stockholm area (Sweden) were carried out on a sample of 8 customers previously recruited and who had experience with the former way of delivering. Interviews were conducted with the customers, first between the 2nd and the 3rd deliveries, and a follow-up interview after the 4th (last) delivery. Interviews were conducted with the delivery drivers, warehouse staff and the e-tailer managerial board. The researchers took part in the deliveries, so observations were also used as input for the theoretical implications.

3.3.5. Paper V

Paper V presents the learnings of a case study (**Paper IV**) and the findings of a structured literature review on home deliveries of food and groceries. The case study includes the concept development and the test in real-life conditions (field-test). Results from the case study showed that there is potential for business growth with the implementation of sustainable packaging logistics innovations provided that the concept is developed with a good integration of the two systems (packaging and logistics). When defining the aim of the literature review, several adjustments in the search terms, and discussions were conducted between the researchers to decide the boundaries of the search and the reasoning for the exclusion criteria. The authors decided to set a broad search on the topic and limit the search to the most recent literature [2015-2022]. The articles were coded in different categories and based on the approach of the study. The findings from the literature review revealed a research gap on the integration of the logistics system and the packaging system. From there – and after exploring the implications and ramifications of the Resource-Advantage Theory – the paper puts forth four propositions exploring the potential

of packaging logistics to increase efficiency in home deliveries of food and groceries and the opportunities to create competitive advantages from it.

3.4. Research quality

Developing research with a quality level that meets the standards of the academic community is the objective of any researcher. Even though there is a belief that assumes that if a paper has been through the review process and has been published, the quality stamp is ensured. This is not necessarily true. Lindgreen's et al. (2021) perspective on the concept of "research quality" is the significance and contribution of a research article to "advancing scientific knowledge and broader considerations about how the research influences practice." On that editorial note, they define 5 conditions to ensure research quality:

(1) Research problems leading to research opportunities – All five papers in this thesis unveil new research opportunities. The categories that emerged in the articles sampled in **Paper I** were used in the discussion of the future research directions for sustainability and circular economy. **Papers' II** and **IV** findings from the empirical data revealed the need for more research. The former reported the need for more empirical studies on how the supply chain setting can affect the environmental impact of the packaging solution. The latter reported the need for more research on circular home deliveries of food and groceries, particularly, the design of the concept in relation to the logistics operations for the viability of the business and the customers' openness to trade the level of their experience for a greener delivery. **Papers III** and **V**, presented with theoretical implications for open research opportunities to assess the concepts and hypotheses, and to verify or refute them with case studies or other empirical studies.

(2) Initiating research stream – The research articles were designed, conducted, analysed, and discussed in close collaboration with researchers that were experts in the topic and familiarised and well acquainted with the methods (source of data collection), methodology (analyses of the data), and the paradigms in discussion.

(3) Clarity in expression – The premisses and the argumentation in the papers are clear and well-grounded in the existing research. The results contribute and add to the existing knowledge and, to some extent, "challenging the status quo" (Lindreen's et al., 2020).

(4) **Teamwork within a network of scholars** – This research has been presented at conferences and shared in different scholarly environments. These interactions between researchers (experts in the topic but also with researchers with quite different backgrounds) contributed to the development of ideas and more solid and relevant contributions.

(5) **Platform to consolidate knowledge –** Even though three of the five papers are not yet published, there is a vision of what the unpublished papers can contribute, and the specific research communities to which they will have the most significance. On the other hand, the thesis is a structured and methodical "platform" on which to consolidate and disseminate the findings of the research papers.

Yin (2014) discusses four conditions (also called quality tests) that must be maximised to ensure research quality: construct validity (3.4.1.), internal validity (3.4.2.), external validity (3.4.3.), and reliability (3.4.4.).

3.4.1. Construct validity

Construct validity refers to the establishment of "correct operational measures for the concepts" being studied (Kidder and Judd, 1986). In other words, the ability to measure what is proposing to measure (Mentzer & Kahn, 1995), and the relevance of those measurements to the purpose of the study. In all five papers presented in this thesis, data collection was conducted according to the established protocols. The data (qualitative and quantitative) collected for each of the papers were found to be the most meaningful and appropriate for the analyses and findings targeted. In **Papers I** and **IV** the research design, sampling strategy and data analyses (and ethical considerations in **Paper IV**) were defined in parallel with the RQs. In **Papers II** and **III** the RQs were the starting point, and the research design and data collection were defined to align with the purpose of the studies. In **Paper V**, an explorative study, the process was more iterative and adjustments on the direction of the paper were made as the findings from the case study and literature review revealed underexplored research paths.

3.4.2. Internal validity

Internal validity refers to the ability to demonstrate a cause-and-effect relationship between the independent and dependent variables and has a strong case showing that those findings are not impacted by a variable that was not accounted for. Internal validity is "only a concern for causal (or exploratory) case studies" and in studies that draw inferences (Yin, 2014). For that, **Papers II** and **IV** are relevant

pieces of research because they consist of case studies that: (1) aim to clarify the relationship between packaging material decisions and the impact from the logistics and supply chain settings by modelling the relevant packaging and logistics activities (**Paper II**); and (2) aim to explore the challenges that emerge from implementing a circular packaging system in a setting involving the final consumer by studying the dynamics and perceptions of the actors involved (**Paper IV**). **Papers III** and **V** are somehow relevant for this condition too, as both infer some propositions and hypotheses based on empirical and/or theoretical data.

3.4.3. External validity

External validity refers to the ability to generalise results beyond the context and specificities of the case study. In all four papers, the conclusions drawn are presented in a way that can be generalised and/or tested in different contexts: the papers that were built based on empirical data (**Papers II** and **IV**) propose theoretical, managerial and policy implications that can be applied in broader contexts, while the papers built from more theoretical grounds (**Paper III** and **V**) aim to progress the theoretical knowledge with propositions and hypotheses.

3.4.4. Reliability

Reliability refers to the possibility to replicate the study which includes data collection and analyses. This is important because it enables the comparison of the same phenomenon applied in different settings and thus the understanding of how the different variables influence (or not), and the extension of that effect. In all five papers data collection was conducted following the methodological protocols in which the steps and decisions on the analyses were described and detailed in the methodology section of each paper.

4. Summaries of the appended papers

This chapter provides a short summary of each paper included in the thesis. The summaries present the most relevant points for the purpose of this thesis.

As mentioned before, the papers build on each other: **Paper I** is a SLR in which the state of the art on industrial packaging is analysed and discussed from the perspectives of the triple bottom line of sustainability and the circular economy. **Papers II** and **III** build on the findings from **Paper I**. **Paper II** is a case study and explores the environmental implications of replacing disposable plastic packaging with fibre-based packaging in a B2B global supply chain. Building on the findings from **Paper II**, **Paper III** discusses the limitations of GWP to fully grasp the harm of plastics that are landfilled and tossed in nature. **Paper III** and proposes other impact indicators ("emissions in water", "freshwater ecotoxicity" and "marine ecotoxicity") to be considered simultaneously with GWP. That would allow a better understanding of the actual harm of plastic waste. **Paper IV** revolves around a field-test of a circular packaging logistics solution applied in a B2C (e-commerce) setting. It describes the field-test and aims at testing the feasibility of the new concept by collecting the feedback from the actors involved in the process. To build on that, **Paper V** suggests four propositions (by merging the findings from a structured literature review, the case study and the Resource-Advantage Theory) to highlight the importance of sustainability-oriented innovations on packaging logistics and on the growth of businesses in the market.

4.1. Paper I

Industrial packaging and its impact on sustainability and circular economy: A systematic literature review

The 98 sampled articles selected from the SLR were published between 1993 and 2022. The study has two Research questions:

Research Question 1 – How can current research of industrial packaging be categorised?

Research Question 2 – What is the state of the art and future research opportunities for industrial packaging regarding sustainability and circular economy?

From the analysis of the sampled articles, four categories emerged (Table 2). Each category has several subcategories that help clarifying the relationship between industrial packaging and: (i) supply chain, (ii) environment, (iii) the development process, and (iv) policies and regulations.

When analysing the sampled articles from the triple bottom line of sustainability, it was possible to see that research focusing solely on the environmental pillar is a rather recent trend that has been growing significantly in the recent years (2015-2020). Nevertheless, the economic pillar is the one that still draws most of the research attention. Due to the trade-offs between economic and the environmental pillars, researchers have been driven to explore both pillars at the same time. This trend is particularly noticeable over the last decade.

From a circular economy perspective, 35 out of the 98 articles considered circularity in the study. Almost 50% of these 35 articles explored the *reuse* and *repair* of packaging; 40% studied *recycling*. The remaining 10% split evenly between *refurbish*/*remanufacture* and *repurpose*. This means that none of the three *R*'s with the most potential for circularity (*refuse*, *rethink* and *reduce*) were discussed.

Table 2.
Categories and subcategories that emerged from the systematic literature review on industrial packaging (adapted from Silva & Pålsson [2022]).

Categories/ Subcategories	Description
Improve supply chain efficiency encompassing industrial packaging	
Transport and warehousing	Assess and improve the relationship between transport, handling, and warehouse/inventory management with industrial packaging.
Organisational structure and strategy	Importance of the internal structure and higher management decisions have on industrial packaging decisions and their implications for the company's performance.
Packaging supplier selection and integration	Importance of supplier selection and supplier integration in the supply chain.
Packaging manufacturing process	Improve packaging production performance and flexibility.
Minimise environmental impact of industrial packaging	
Recycle and reuse	Characteristics of recyclable and reusable industrial packaging and the consequences of their use – impacts, benefits and possibilities.
One-way vs. returnable	Comparison of the environmental impacts between one-way and returnable packaging strategies.
End-of-life	The environmental impacts of the end-of-life processes and waste management.
Enhance industrial packaging development process	
Guidelines	Recommendations and principles to improve and support the packaging development process.
Methods	Methods to assess and improve packaging development decisions.
Tools	Software programs and tools to support decision-making process.
Implications of industrial packaging regulatory compliance	
Environmental regulation	Regulations and policies that promote environmentally friendly decisions and restrict decisions and behaviours in industry.

This literature review was developed to clarify current knowledge, identify research gaps, and discuss implications. Additionally, it was designed to support practitioners and other entities (e.g., policymakers) that consider industrial packaging a relevant topic, aiming to enhance the sustainability of industrial packaging practices.

4.2. Paper II

Replacing plastic with corrugated cardboard: A carbon footprint analysis of disposable packaging in a B2B global supply chain – A case study

This study is based on an LCA conducted on a case study from the ICT industry. The ICT company is moving towards plastic-free packaging solutions, and the study aimed to assess the environmental impact (particularly focused on the CO_2-eq. emissions) of replacing plastic cushioning with fibre-based cushioning. The comparison considered three packaging solutions: two with plastic cushioning (one with EPP, Option 1; another with EPE, Option 2 and the third with a fibre-based cushioning, Option 3). All three packaging solutions were assessed together with their respective corrugated cardboard boxed because all three packaging solutions required boxes with different measures and weighs. This shift not only had the impact of the packaging material and the weight (and volume), but also the locations from where the materials were sourced.

To have a clearer picture of the real impacts, the assessment was carried out for the total number of units shipped to the customers worldwide for the year of 2020. The analysis included the transport modes and distances travelled throughout the supply chain: from packaging manufacturers to transport suppliers, to the case company plants, to the distribution hubs, to the customers and finally to the EOL management.

Some assumptions were required for the calculations from the EOL. The first one was the splitting up of the processes: how much of the packaging waste goes through recycling, combustion, and landfill. It was decided to group the countries based on regions (Kaza et al., 2018) for the purpose of simplicity.

Results showed that the increase in weight from the plastic-free packaging (compared to the plastic options) led to a significant rise in transport emissions. Long distances and dependence on air transport connecting the case company's plants to customers (global supply chain) were the main reasons for the less positive environmental performance of the plastic-free packaging. CO_2-eq. emissions are represented in two different graphs in Figure 4. Graph A (on the left) splits the

emissions based on the life cycle processes: manufacturing (which also includes material extraction), transport, and EOL processes. In graph B (on the right), emissions are represented in the supply chain in a cumulative graph to display how each of the stages contributed the most to CO_2-eq. emissions.

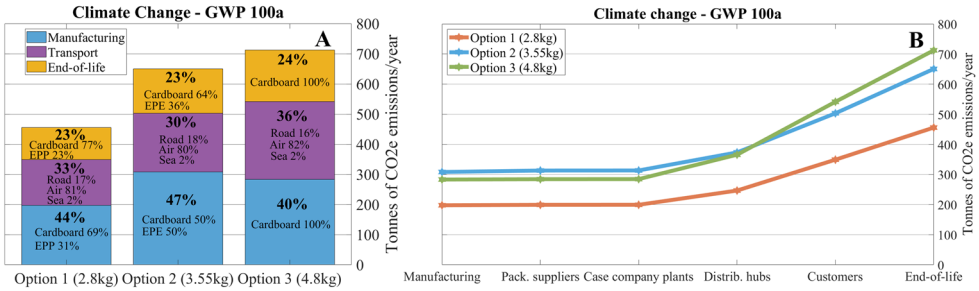

Figure 4.

Results from LCA comparing three packaging solutions: Option 1 and Option 2 using plastic cushioning, and Option 3 using corrugated cardboard cushioning. Graph A shows the emissions split by process (Manufacturing, Transport and EOL). Graph B is the cumulative graph of the emissions throughout the supply chain (Silva & Molina-Besch, 2023).

Other sustainability dimensions were considered in this study – terrestrial ecotoxicity, human toxicity, marine ecotoxicity and fossil depletion. The plastic-free option performed better than Option 2 in three of the four dimensions.

Some implications were drawn from this study, particularly: (1) that it is important to consider the supply chain context (distances and transport modes) when taking decisions that impact the weight of the packaging, (2) the waste management depends significantly on the region in which it will be disposed of and that should be considered in the packaging development phase, and (3) policymakers should reform plastic policies with other policies on the transport of goods to avoid transferring the environmental burden.

4.3. Paper III

Do LCAs encourage landfilling of plastic waste? Testing and proposing LCA impact indicators to complement GWP analysis

The way waste is managed is crucial and critical for the environment and for the sustainability goals. GWP is, typically, the most widely used impact indicator when conducting LCAs. However, this impact indicator does not seem to capture accurately the impacts of non-biodegradable materials (and particularly plastics) ditched in nature. This is because the degrading process of such material is primarily

physical. This means that the emissions that result from that process are significantly lower than those released by biodegradable materials in similar EOL processes in which the material degrades over time. On the other hand, the fact that EOL (in general) and landfilling of plastics (in particular) can have such a small effect on the overall results of the GWP takes away responsibility to ensure that the waste produced is managed in a sustainable way.

This research article aims to bring for discussion the need for more accurate ways to measure the impact of non-biodegradable materials and to complement the GWP results: GWP can be an accurate way to measure landfilling of biodegradable materials and understand the supply chain context (as it can capture well the indirect effects from logistics), yet, it does grasp the impact in the processes where there is no emissions released.

For the following analysis, EPP and EPE plastics were selected as they are two of the most used types of plastics in packaging. All the impact indicators available in the database Ecoinvent® (v.3.10) were run for the landfilling of these materials and then compared against the impacts from landfilling corrugated cardboard (baseline) (Figure 5).

This analysis showed that "Emissions to water – monetary impact value" as well as "ecotoxicity freshwater", and "ecotoxicity marine" were the impact indicators with the biggest difference between the effects from landfilling corrugated cardboard and plastics (EPP and EPE). The impact indicators with highest potential to better represent the real consequences of non-biodegradable materials were used in a case study (same case study used in **Paper II**) to compare the results between assessing these materials based on their GWP impact and based on the three impact indicators mentioned.

While the GWP analysis showed that the fibre-based packaging solution was the one performing the worst (applied in that specific supply chain context), the results based on the impact indicators "emissions to water" and "ecotoxicities (freshwater and marine)" were quite different. Results showed that the best packaging solution based on GWP (100a) was in fact the worst option when analysed through "emissions to water" and "marine ecotoxicity" methodologies (Figures 6A and 6B). When applying the "freshwater ecotoxicity" impact indicators the EOL impact from the fibre-based packaging were significantly lower than of the plastic packaging. However, it did not necessarily mean that overall, the fibre-based option was the packaging with the lowest impact, as EPE had lower overall impacts (Figure 6C).

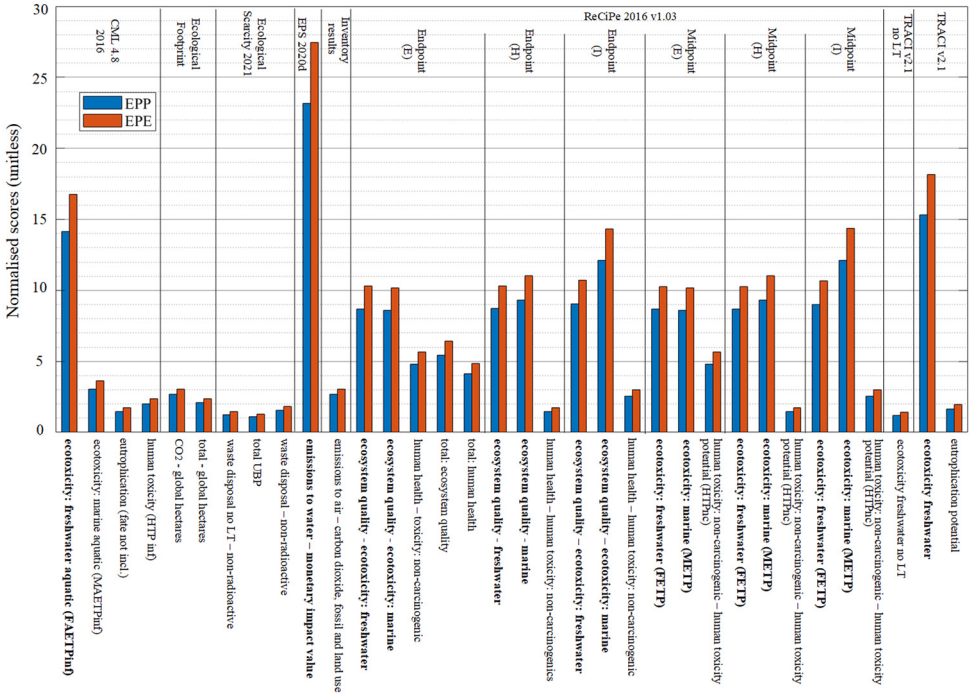

Figure 5.

Normalised scores (unitless) using as baseline the impacts from Option 3 – plastic-free packaging based on four variations of IPCC 2021 for climate change analysis (fossil no LT GWP100; fossil including SLCFs no LT GWP20; fossil GWP100; and fossil, including SLCFs GWP20). Option 1 EPP plastic, Option 2 EPE plastic, Option 3 corrugated cardboard.

These results bring forward to discussion the importance of considering more than one impact indicator for more robust and insightful decision-making processes. The fact that landfilling of plastics seems to be underplayed may uncover an indication that GWP is justifying the extensive use of this EOL process for plastics, even though it is well established that landfilling is the least desired (and least circular) EOL process.

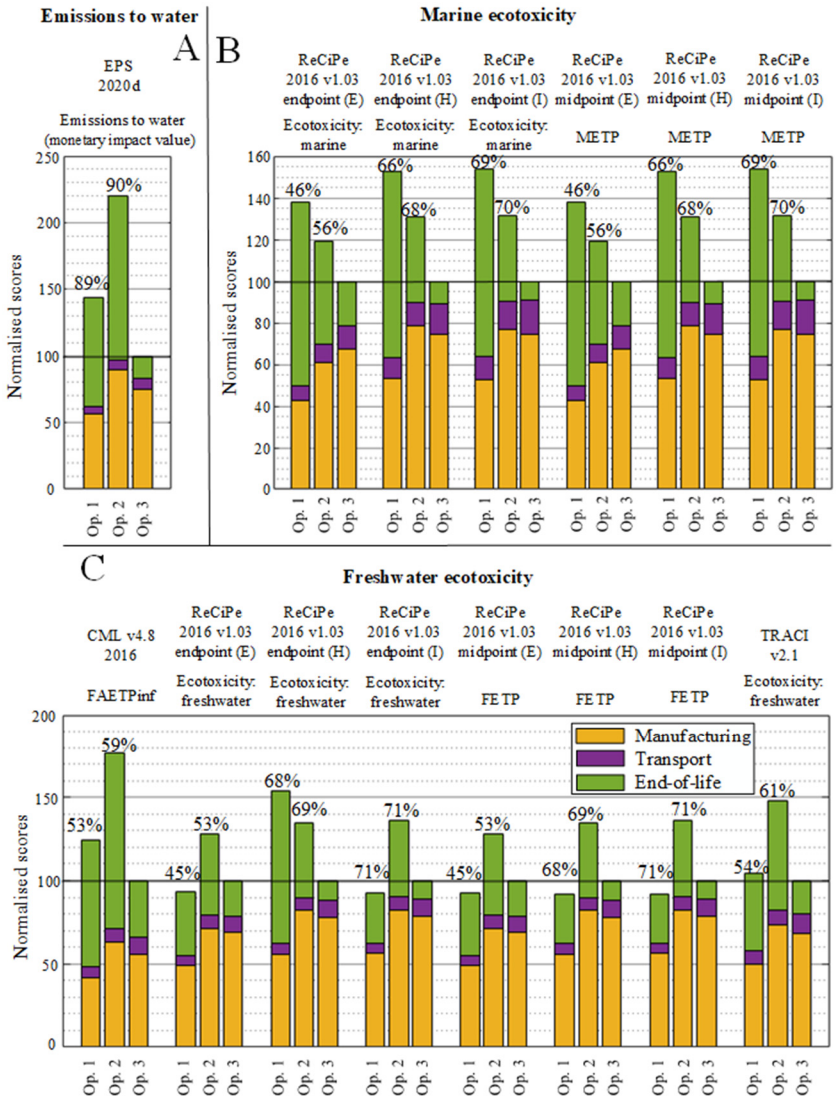

Figure 6.

Normalised scores (unitless) using as baseline the impacts from Option 3 – plastic-free packaging. The analyses are based on A) Emissions to water; B) Human toxicity, C) Freshwater ecotoxicity, and D) Marine Ecotoxicity. Option 1 EPP plastic, Option 2 EPE plastic, Option 3 corrugated cardboard (Silva, 2024).

4.4. Paper IV

Exploring the circular last mile: Reusable packaging in home delivery of food and groceries using a design science approach

The market for home deliveries of food and groceries has been expanding in recent years, leading to increased environmental impacts such as emissions from deliveries, energy use for the cold chain, and packaging waste. This paper aims to support the development of circular retail supply chains focused on customer involvement and logistics in home deliveries. Using a design science approach, the study developed a "circular delivery concept", tested it in real-life conditions, and analysed the results through interviews, observations, and workshops.

This paper follows and reports the 3 (required) phases of a design science approach – (1) Solution incubation, (2) Solution refinement, and (3) Explanation I – Substantive theory (Figure 7). The first phase refers to the development of the artefact (i.e., the concept that is proposed). The second phase refers to the testing of that solution and the assessment of its potential through the analysis of data collected in the field-test. The third phase refers to the deduction of theoretical and practical implications based on the previous phases.

The empirical findings from the field-test were clustered and analysed. Semi structured interviews to the customers (one after the second delivery and a follow-up interview after the last round), warehouse staff and delivery drivers were conducted. The managerial board was also interviewed after the last round of deliveries. The inputs were aggregated and summarised.

Overall, customers were positively impressed with the experience. The value added from splitting the box into two compartments to reduce the weight and pressure on the products, and thus, reduce the risk of food spoilage was recognised. Because the box was non-foldable made its storage and return non-consensual and of particular concern for those living in smaller apartments. The environmental focus of this concept was not mentioned in the interviews, and no customer reacted to or speculated about it.

Stability of the orders during the expedition, higher convenience, and better ergonomics when loading the van and picking up the orders were improved aspects acknowledged by the drivers. The bulkiness of the packaging and the fact that it could not be folded could result in a challenge concerning the space in the van if customers returned several boxes at the same time.

PHASES (Holmström et al., 2009)	OBJECTIVE	MEANS	ACTIVITIES	ACTORS
PHASE 1: Solution Incubation	• Reduce environmental impacts from: • Energy to produce cold • Disposable packaging	• Development of a reusable insulated biodegradable unit packaging concept to replace disposable packaging	• Define system boundaries • Gather experts and supply chain's entities to support the development of the artefact	• Researchers •Packaging supplier • E-tailer • IT developer
PHASE 2: Solution Refinement	• Test the artefact in real-life context • Use the inputs collected from the field test to improve the concept • Use the inputs collected to refine the packaging solution	• Control of temperature and humidity inside box • Assess packaging aspect after each loop • Assess reverse logistics' extra activities • Customer openness and satisfaction	**Field-test – 4 rounds of deliveries to 8 customers** • Observations: • Packaging robustness • Impacts on the logistics operations • Interviews: • Customers • Warehouse personnel • Delivery drivers • E-tailer managerial board • Tracking temperature and humidity of orders	• Researchers • Packaging supplier • E-tailer • IT developer • Sample of customers • Delivery drivers • Warehouse personnel
PHASE 3: Explanation I - Substantive Theory	• Advance and operationalise supply chain theories including final customers and on circularity	• Review results and deduce theoretical and practical implications	• Analyse and organise inputs from the field-test	• Researchers

Figure 7.

Design science research process: the objectives, means to achieve them, activities, and actors involved in each of the Phases (Holmström et al., 2009).

The routine in the warehouse was significantly impacted by the new set-up, causing some concerns to the staff. The inspection of the packaging was one of the main concerns. This was because the impact of poor inspections can have serious consequences such as risking the quality of the food through contamination. Another concern was the space taken by the boxes and the exposure to cold temperatures that can result in damaged packaging.

Even though the e-tailer managers recognised the potential from the concept and found the field-test to be a suitable way to collect evidence on both the business potentials and the implications in the logistics operations, they were concerned with some challenges that were found to be potential causes for disruptions and major problems for the e-tailer. For example, the scaling-up of all the adjustments in the logistics activities would be difficult to execute without significant investments. Another example was that the manpower and storage space would require restructuring to operationalise the processes. On the other hand, these investments could only be justified with clear environmental benefits and a market advantage. The market advantage was not as evident as the managers had expected, particularly in relation to the reactions from customers. One way to motivate them could be through effective communication, especially by quantifying the positive aspects and comparing them to the previous (linear) deliveries.

This study concludes that, from an operational perspective, businesses should adjust their processes and explore improvement opportunities while recognising the potential of circularity and sustainable practices. Moreover, the changes needed in production and reverse logistics should be seen as strategic investments rather than operational adjustments due to the added costs. Policies act as a driving force towards carbon-neutral supply chains and should encourage academics and industry practitioners to develop technologies and methods for achieving more sustainable targets. This can be accomplished through approaches like industrial symbiosis, which strategically reduces impacts and waste.

4.5. Paper V

Sustainable packaging logistics innovations in home delivery: Enabling competitive advantages for retail actors based on Resource-Advantage theory

E-commerce actors strive to make logistics operations as efficient and effective, to reduce the costs as much as possible and to keep a high-quality service to make their margins healthier (McKinsey, 2021). Tackling the typical challenges in e-commerce logistics demands a strong set of capabilities (Deloitte, 2021), and thus, constitutes a great possibility for e-commerce actors to gain a competitive edge. However, the fact that logistics and packaging are still regarded as two independent dimensions in the efficiency in home deliveries of food and groceries, represents a hurdle to more sustainable and viable delivery systems.

In this study, the findings from a case study (**Paper IV**) are discussed to illustrate both the challenges and the opportunities of implementing packaging logistics innovations in the context of e-commerce. This sustainable development is important to operationalise sustainability to converge with the expectations from external pressures from policymakers and from the market. This research paper builds on that premise to bring forth a set of propositions in which it is merged the importance of sustainability-oriented innovations in packaging logistics and the Resource-Advantage Theory to discuss the unexplored potentials of improving the business competitiveness.

The Resource-Advantage Theory defends that for a firm to perform on a higher level, it must acquire and leverage strategic resources. The deployment of strategic resources is crucial to ensure that the sustainability-oriented innovations are viable to be implemented and constitute the means to improve efficiency and effectiveness of the operations.

Four propositions are discussed for the integration of packaging logistics with the R-A Theory.

- **Proposition 1:** Implementing circular and reusable packaging systems in home deliveries of food and groceries optimises the use of material resources and aligns with a circular economy, which, in turn, leads to a competitive advantage.

- **Proposition 2:** The use of temperature-controlled packaging reduces the need for refrigerated vehicles and enables unattended deliveries at the doorstep, through parcel lockers, or reception boxes. This minimises energy usage and increases delivery efficiency, which, in turn, leads to a competitive advantage.

- **Proposition 3:** Integrating packaging design with logistics processes and distribution channels enhances logistics efficiency, reduces environmental impacts and provides value-added services for customers which, in turn, leads to a competitive advantage.

- **Proposition 4:** Collaboration between retail actors (both vertically and horizontally) reduces packaging assortment and complexity, and improves logistics flexibility and efficiency, which, in turn, leads to a competitive advantage.

The aim of the propositions it to explore the potential of better integrating packaging and logistics in home deliveries of food and groceries and gain a competitive advantage in the market by optimising resources consumed and deployed in the processes.

5. Findings

The research findings are presented in this chapter to more evidently show how they contribute to the goal of the thesis. This chapter starts by describing how the studies help to answer RQ1 and RQ2 and concludes with a few points on how the study findings contribute to and advance knowledge on the integration of sustainable industrial packaging for greener and more competitive businesses.

Overall, this thesis contributes to the research gap on the environmental impacts and opportunities from sustainable industrial packaging. As defined in Section 1.3. of the Introduction, the thesis's aim was to answer:

RQ1: *What key* aspects *should be considered when planning and implementing sustainable industrial packaging initiatives?*

RQ2: *What are the challenges of implementing circular industrial packaging solutions in B2C settings and how to turn them into efficiency and competitiveness?*

Paper I has a broader scope and sets the scene for the four following articles. It contributes to the reasoning and development of the two research directions that resulted from the papers that followed (Figure 8). The following papers bring different standpoints that contribute with knowledge that help to answer the RQs. **Papers II** and **III** build on each other to help answer RQ1 and **Papers IV** and **V** build on each other to help answer RQ2. In both streams the findings from the empirical studies (**Papers II** and **IV**) were the triggering points for the following studies that contributed with theoretical implications for RQ1 and RQ2 (**Papers III** and **V**).

To answer RQ1 two key aspects that should not be overlooked when companies plan and implement sustainable packaging decisions come from **Papers II** and **III**. First, the importance of considering the aspects that are directly and indirectly affected by the packaging changes (**Paper II**). Second, the importance of acknowledging that different materials can harm the environment in different ways and that other impact indicators should be considered for a more complete assessment of the packaging solutions when applying an LCA (**Paper III**).

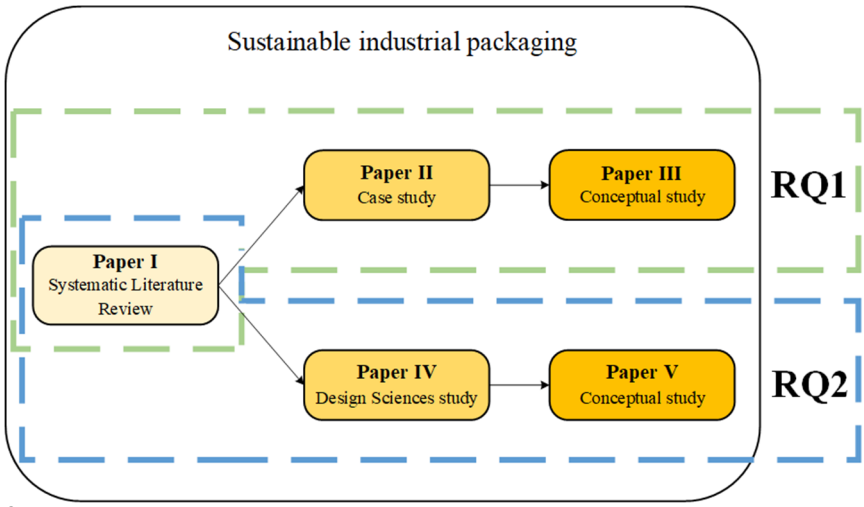

Figure 8.

Representation of which papers contribute to each of the RQs: **Paper I** supports both research streams, **Papers II** and **III** contribute to answering RQ1. **Papers IV** and **V** contribute to answering RQ2.

These two key aspects can be probed further. The first key aspect can be broken down and contribute to the discussion by introducing five important aspects. **First**, by shifting from one packaging material to another, the respective impact can be transferred from one process to another. In other words, the process that causes the most environmental harm is not necessarily the same for different materials. Thus, it is important to considering all the processes in the life cycle of both materials in a study. **Second**, when assessing the environmental impacts of packaging through LCAs, the logistics processes can be impacted in different ways by different packaging solutions, such as transport, operations in warehouse or any other logistics activities (including outsourced ones). **Third**, it is not just because the material selected is more sustainable, that it necessarily leads to a favourable aftermath in all dimensions of environmental sustainability. **Fourth**, weight (and volume) of the packaging can have such an impact that it inverts the "expected positive" results. **Fifth**, even though a material is recyclable there are considerations to take, particularly in the context in which the packaging will turn into waste. This can have a great impact on the waste management process, particularly with waste ending up in landfill or burnt, and then, have a totally different environmental impact than what was accounted for when designed (possibly to be recycled).

The evaluation study (**Paper III**) builds on that knowledge, particularly delving into the third point presented above – the fact that environmental sustainability has multiple dimensions and can be assessed by different metrics can create ambiguous results. The most widely metric used to measure "environmental sustainability" in LCAs is CO_2-eq emissions, however, in **Paper III**, it is argued that it may not be

the most suitable to assess the impact of plastics, particularly when comparing it with bio-degradable materials. When the LCA (assessing the CO_2-eq. emissions) compares two scenarios in which one does not contribute to the emissions in similar ways, a bias is created. Therefore, it is argued that in such cases, the LCA analysis should include other metrics to better capture the impacts. Biodegradable materials can release high levels of CO_2-eq. emissions when degrading in nature. Corrugated cardboard, for example, releases significant levels of methane (a gas with a high factor when translated to CO_2-eq. [Grubert & Brandt, 2019; Pachauri et al., 2014]), resulting in high GWP impacts. On the other hand – and because plastics are non-biodegradable – the emissions are not a significant consequence of its landfilling. The degradation of plastics is primarily physical, resulting in the breakdown of plastics into smaller pieces, such as microplastics and nanoplastics. This mismatch between the actual harm and what is accounted for in the GWP results is an underrepresentation of the real harm from plastics and can lead to misleading results or even be used to greenwash certain "less green" decisions. Although outside the primary scope of the paper, it is still relevant to note that, from a logistics perspective, the CO_2-eq. emissions metric can be problematic. Comparing the impact of fossil-based vehicles to electric vehicles based solely on this metric can result in a bias towards electric vehicles: electric vehicles affect the environment in ways beyond CO_2-equivalent emissions, particularly through their batteries (maintenance processes, and EOL processes [Verma et al., 2022]).

To answer RQ2, the results from **Papers IV** and **V** contribute three relevant points to the discussion. Two of the points are addressed in **Paper IV** and refer to the challenges and opportunities of implementing a circular packaging logistics concept in the context of home deliveries of food and groceries: **First**, the fact that building on a logistics system defined to be optimal for a linear setting can be challenging and even make the concept of circularity seem unviable. **Second**, it refers to the interaction of circular packaging with customers and their willingness to collaborate to reduce the environmental impact of the deliveries. **Third,** addressed in **Paper V**, refers to the opportunities that can emerge from innovations in sustainable packaging logistics can efficiency in their operations, thereby creating a competitive edge over other market actors.

When analysing the design science study (**Paper IV**) the findings are relevant to understanding the potentials of sustainable innovations. They are also relevant to the logistics challenges and to implementing reusable packaging in the context of last mile deliveries of food and groceries. Even though from a small sample, the customers showed openness to compromising their "hassle-free" delivery for one in which they had to have an active role to facilitate the return of the packaging. Nevertheless, it is not to completely understood the extension of that commitment and how that can impact their preferences as customers in the medium- and long-terms. In any case, the field-test showed that there is potential for such innovations,

and that with a more well-thought-out plan (i.e., a concept in which the logistics activities are defined for the circular business model) can unveil more efficient ways for home deliveries of food and groceries.

Overall, both RQs emphasise the importance of considering *integration* for sustainable, viable and successfully implemented sustainable packaging solutions. Integration of processes and entities of the supply chain, as well as the integration of different dimensions of sustainability are some of the points discussed in the papers to reduce the risks of overlooked consequences or uncertain aftermath. The integration of resources (tangible and intangible) is also a critical aspect referred to in the articles. Integration requires collaboration, strategic alignment and agility, yet it fosters the sustainable development from multiple perspectives and dimensions.

6. Discussion

The research is discussed from different perspectives in this chapter. The first one is on how each of the four articles (Papers II, III, IV, and V) falls in and contributes to the research streams identified in the systematic literature review (Paper I). After that, three other perspectives are discussed: dilemmas in managing sustainable industrial packaging (6.2), packaging waste management (6.3) and then, the intricacies of industrial packaging in a B2C context (6.4).

In this section the research is discussed from different perspectives. First, the four articles (**Papers II**, **III**, **IV**, and **V)** are organised according to the categories and subcategories identified in the SLR (**Paper I**) (Figure 9). It discusses the main findings and contributions to the knowledge reported in the SLR. After that it is discussed the main dilemmas of each of the four papers, followed by a discussion on two perspectives that are found to be relevant contributions of the thesis. First, the waste management and how the B2B and B2C contexts can impact the way packaging is managed after turning into waste. Second, the dynamics and challenges of industrial packaging in a circular context.

6.1. Categories and subcategories of industrial packaging

Based on the categories and subcategories identified in the SLR (**Paper I)**, **Papers II**, **III**, **IV**, and **V** were organised using the same criteria applied in the paper. Figure 9 shows that **Papers II** and **III** contribute to the same category ("Packaging development process") and subcategory ("Guidelines") while **Papers IV** and **V** fall in the same category ("Supply chain efficiency") but in different subcategories: **Paper IV** contributes to the subcategory "Transport and warehousing" while **Paper V** contributes to the subcategory "Organisational structure and strategy".

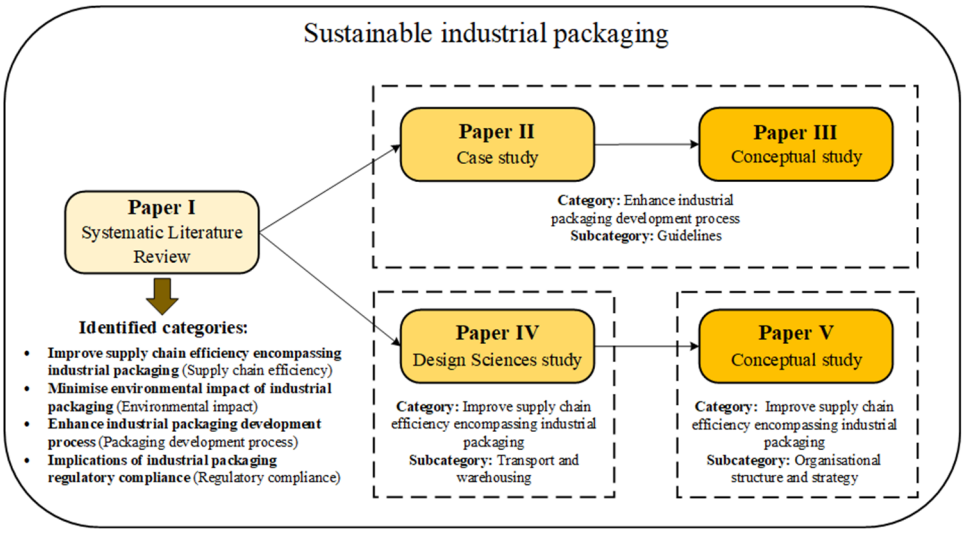

Figure 9.

Representation of the categories and subcategories identified in **Paper I** (Silva & Pålsson, 2022) to which **Papers II**, **III**, **IV**, and **V** contribute.

Paper II – This paper falls into the category "Enhance packaging development process" and the subcategory "Guidelines". It contributes knowledge on some aspects that should be paid attention to in the packaging development process. **Paper I** explains that this subcategory revolved around aspects related to "safety, ergonomics, sustainability, logistics, marketing and legal restrictions". The findings of **Paper II** have relevance, particularly for the environmental pillar of sustainability and logistics efficiency. For example, packaging weight can impact the emissions from transport so negatively that it can outweigh the savings in the packaging manufacturing process. Thus, when designing a packaging solution, weight should have a high precedence, particularly when the supply chain relies on transport modes with high CO_2-eq. emissions per km travelled, such as air transport.

Paper III – This paper falls into the same category and subcategory as **Paper II** "Enhance packaging development process" and "Guidelines", respectively. The paper contributes to this research stream by arguing that landfilling plastics can have severe and disruptive effects on natural habitats. It also contends that using inappropriate metrics can help "legitimise" disposable packaging lacking circularity and validate that linear packaging solutions have much lower impacts compared to reusable ones. By including this in the discussion, this paper clarifies that there are other environmental effects besides the popular CO_2-eq. emissions and packaging companies should be conscious of them in the development process phase.
Paper IV – This paper falls in the category "Improve supply chain efficiency encompassing industrial packaging" and the subcategory "Transport and

warehousing". Its contribution revolves around the relationship between packaging and logistics, specifically the transport and warehousing activities. Based on the findings from empirical data, it contributes to discussing the challenge of implementing an efficient packaging logistics system when built on top of a linear one with, arguably, minimal adjustments. **Paper I** reported that financial restrictions are the main barriers to the implementation of reverse logistics (based on the findings from Yusuf et al. [2017] and (Lira et al. [2018]). This was also the main concern of the managerial board of the e-business after the field-test.

Paper V – This paper falls into the category "Improve supply chain efficiency encompassing industrial packaging" and the subcategory "Organisational structure and strategy". This subcategory refers to the fact that there are some internal structures that hinder the adoption of different strategies. Additionally, extra resources are often not allocated because they are deemed non-critical to the business or considered risky. Even though they are often seen as non-strategic, not implementing them may prevent the growth of the business. **Paper V** argues that with the right resources (meaning among other points, a structured plan and willingness to collaborate with the actors in the supply chain [suppliers and even customers]) one can reveal the potential and increase the company's efficiency and potentiate market growth.

6.2. Dilemmas in managing sustainable industrial packaging

In line with the discussions addressing RQ1 and RQ2, this section discusses the main dilemma in each of the four papers (**Papers II** to **V**) (Figure 10). In this context, dilemmas are situations where different dimensions of sustainability push in opposite directions: **Papers II** and **III** deal with dilemmas within the environmental pillar of sustainability, whereas **Papers IV** and **V** address dilemmas between the economic and environmental pillars of sustainability.

Each dilemma is briefly discussed according to the classification by Prendeville et al. (2017), which identifies four categories of dilemmas: <u>tensions</u> (when two options have different pros and cons), <u>hierarchies</u> (when a certain decision or strategy is given higher precedence and rules out other possibilities), <u>contradictions</u> (when improving one environmental dimension results in poorer performance in another dimension), and <u>oversights</u> (when focusing on certain aspects leads to overlooking other important ones).

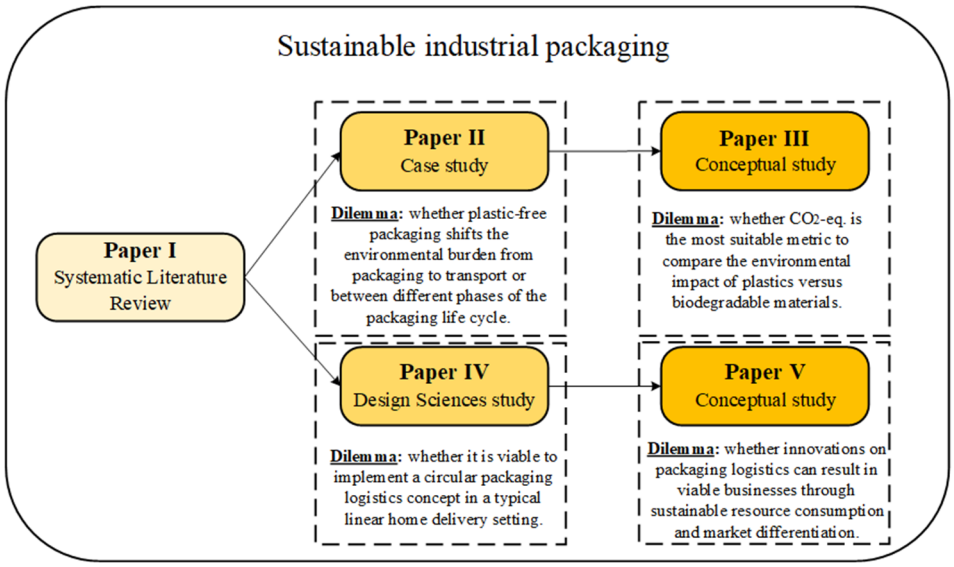

Figure 10.

Representation of the main dilemmas of each of the four papers (**Papers II** to **V**).

Paper II dilemma: whether plastic-free packaging shifts the environmental burden from packaging to transport or between different phases of the packaging life cycle. In this paper, results from the LCA led to a dilemma in which the company had to decide whether to focus on reducing their plastic consumption or their carbon footprint. This dilemma falls under the category of "contradictions", as the case study showed that a more sustainable (fibre-based) packaging solution would have led to an increase in emissions. In other words, improving one environmental dimension (such as reducing plastic consumption and waste) would have negative consequences for a different environmental dimension (CO_2-eq. emissions).

Paper III dilemma: whether CO_2-eq. is the most suitable metric to compare the environmental impact of plastics versus biodegradable materials. In this paper, results showed that depending on the metric considered, different packaging solutions could be identified as the "greenest", and that no single packaging solution could optimise all the metrics analysed. This dilemma falls under the category of "tensions". The paper showed that the packaging option with poorer performance in CO_2-eq. emissions resulted in better performance in certain metrics (impact indicators), particularly ecotoxicity.

Paper IV dilemma: whether a circular packaging logistics concept can be viable in a home delivery of food and groceries. In this paper, results showed that there is potential to implement a reusable packaging system, however some aspects need to be carefully addressed. Firstly, the fact that customers become active actors in this

concept and there must be a clear driving force for them to collaborate. Secondly, the new operations need to be implemented in a way that keeps them agile, reliable, and robust (i.e., without increasing risks in the process). This dilemma falls under the category of "hierarchies". Since businesses prioritise financial aspects, and therefore, these needs must be fulfilled before they can delve into and commit to the environmental considerations.

Paper V dilemma: whether innovations on packaging logistics can lead to viable businesses through sustainable resource consumption and market differentiation. This dilemma also falls under the category of "hierarchies" and has a similar reasoning to that in **Paper IV**: the viability of the business (profitability and market growth) has precedence when determining its strategic positioning. If that premise is not fulfilled companies, typically, retract from implementing environmentally sustainable activities.

These dilemmas are challenging to address and represent extra pressure for companies to compromise on certain aspects, and potentially lead to further dilemmas. For example, in **Paper II**, when facing the dilemma of plastic-free packaging vs. emissions ('contradiction'), the company must prioritise which dimension to give higher priority ('hierarchy'). If this priority becomes a strict requirement for all following decisions (e.g., implementing a plastic-free policy), it may constrain other decisions, making the priority dimension outweigh other environmental considerations. Consequently, this could lead the company to make decisions that favour one aspect over others, regardless of the broader impact on other dimensions, such as emissions or consequences from poor packaging waste management.

6.3. Packaging waste management

Companies define their sustainability strategies and take measures to reduce the impact of their packaging by investing on eco-design (Bouhlel et al., 2023). In the process of developing and designing the packaging, companies assume that the waste will be managed in a sustainable manner. However, what happens to packaging after it becomes waste is difficult to predict. Waste can be mishandled due to different reasons, from as basic as (1) lack of commitment to sort and deposit the waste in the recycling bins, (2) lack of sustainable education and awareness, (3) waste being contaminated (e.g., grease or industrial oils), or (4) simply by convenience; to more complicated ones, such as lack of infrastructure for recycling, or materials that even though can be recycled, ask for a too complex or too expensive recycling process. Therefore, optimising resources and defining the "strategic

resources inputs" early in the development and design phases is essential for the alignment of green practices.

The misalignment between what is assumed to happen to the waste and what happens can result in negative effects and even cancel all the efforts put upstream. For example, it has been found that "nearly 80% of the packaging materials are mixed into domestic garbage" (Dai et al., 2021). This means that materials that could have been recycled are mishandled and end up in landfills or burnt. For that reason, and to progress towards sustainable packaging and sustainable waste management, businesses need to collaborate more and integrate their strategies to attain sustainable results. Besides that, companies must look at the impacts beyond their direct actions. GHG protocol can be a structured way of approaching it (Garcia & Freire, 2014; Hertwich & Wood, 2018). It has been reported that Scope 3 (i.e., the indirect emissions [the scope in which waste management falls] can be responsible for more than 75% of the total emissions of the supply chain (Huang et al., 2009). The indirect impacts are often difficult to control and because of that, companies tend to overlook them. Yet, Scope 3 should be taken as seriously as the two other scopes (Scope 1 refers to the direct emissions and Scope 2 refers to the emissions to power the business) (Bacas & Dylla, 2024).

6.4. Industrial packaging meets customer

According to McKinsey (2023), the most suitable scenarios to implement reusable packaging are those "where long-distance transport and washing can be avoided, where many rotations can be guaranteed, and where companies and consumers do not have to invest in parallel setups or add unnecessary complexity to the supply chain". However, a challenge emerges when customers need to be actively involved in the returning of the packaging (Pfoser et al., 2022) and the aspects that customers value to take on new responsibilities need to be factored in.

Home deliveries of food and groceries are valued by customers, not only because it saves them time and stress, but also because of the higher quality of the products delivered (Bjørgen et al., 2021). These high standards of product quality require an attentive selection of the groceries (e.g., longer shelf life) as well as careful handling and transport (Göransson et al., 2018). Packaging plays an important role in the customers' purchase intention (Lydekaityte & Tambo, 2020; Vilnai-Yavetz & Koren, 2013) and in their perception of food safety and quality (Bumbudsanpharoke & Ko, 2022). It is worthwhile to leverage these points, which are highly valued by customers and have the potential to reveal their receptiveness and willingness to overlook less favourable aspects of the delivery, such as handling, storing, and returning responsibilities.

Most e-commerce businesses have similar positioning in the market and offer similar services, ones that emphasise low cost and short delivery times. However, there are more paths for a sustainable development of businesses that can lead to strategic improvements and competitive advantage, thus resulting (as the Resource-Advantage Theory defends) in superior financial performance of the business and the supply chain actors involved in e-commerce settings.

Customers may, however, react in different ways to reusable and recycled products. Studies exploring this topic find different results. On the one hand, some studies find that customers tend to misjudge green products and processes and associate them with lower quality (Bharani et al., 2024). They also have concerns about the impact of reused products on hygiene and safety (e.g., Borg et al. [2020]). On the other hand, some studies report on the customers' openness to using green packaging to the extent they are willing to pay extra for it (e.g., Wang & Hazen [2016]).

B2C supply chains have higher engagement on green practices than B2B supply chains, with top management and trust between actors being, for the latter, an important driver for that shift (Hoejmose et al., 2014). On the other hand, the difficulty of implementing more efficient and sustainable systems magnifies the potential of every step towards that goal, and therefore, the importance of capabilities to drive competitiveness (Deloitte, 2021). As mentioned earlier, dynamic capabilities are crucial for businesses to operate sustainably and efficiently. These capabilities enable businesses to "integrate, build, and reconfigure competencies" and adapt in a market shaped by competitive dynamics (Varadarajan, 2023). Dynamic capabilities in the context of this thesis refer to the knowledge and competence in packaging and logistics and their integration into the decision-making process.

7. Concluding remarks

The main points discussed in this thesis are summarised in this chapter, along with the theoretical and practical contributions (7.1). The limitations of the research presented are also acknowledged as well as suggesting opportunities for future research (7.2).

The challenge of packaging has intensified in recent years, as has the research aimed at minimising its environmental impact. However, the market emphasis on efficient logistics can obstruct the implementation of more sustainable practices. On the other hand, certain sustainability-oriented decisions may result in undesirable consequences, as there is a real risk of transferring the environmental burden between processes of the life cycle as well as to the logistics processes or packaging solutions.

Dilemmas emerge when there is a conflicting result between two or more options. Thus, the importance of broader considerations in terms of the system (supply chain) included in the analysis (as opposed to a simplification based solely on the implications "indoors"), but also in terms of the approaches applied to assess and measure the implications of sustainable decisions. Dealing with these dilemmas can be a challenge that makes firms less bold to invest and more exposed to harmful consequences to their businesses. Being aware of these dilemmas is crucial for companies to have a more robust and insightful decision-making process and to reduce the risk of unforeseen negative outcomes.

7.1. Research contributions

This thesis contributes both theoretical and practical insights on sustainable industrial packaging. Even though the research presented in the papers focuses on industrial packaging, some insights can be extrapolated and adjusted to consumer packaging as well.

Research on sustainable packaging is growing and seeks to support industry in understanding the intricacies of the subject (Bradley & Corsini, 2023). Managers' ambition to implement measures that reduce the environmental impact of their

packaging and logistics systems is also growing. Yet, there is still some misunderstanding on how some decisions can impact the environmental performance of the business and other parts of the supply chain (upstream and downstream).

This thesis contributes to several research streams in industrial packaging. **Paper I** organises the existing research (1993-2020) and, from there, suggests future venues for research to explore. **Paper II** contributes to the considerations when developing sustainable packaging (subcategory: Guidelines). **Paper III** contributes to a better understanding of how to assess the real impacts of plastic pollution by proposing other impact indicators to be included in the LCAs and complement the GWP analysis (subcategory: Guidelines). **Paper IV** contributes to the effects of packaging on supply chain efficiency, particularly in the transport and warehouse operations (subcategory: Transport and warehouse). **Paper V** contributes propositions of how businesses should structure their approach for viable innovative ideas on sustainable packaging logistics (subcategory: Organisational structure and strategy).

7.1.1. Contributions to research

The contributions to research have been touched upon throughout this thesis, with each of the papers having a relevant contribution to the existing body of literature on sustainable industrial packaging. Packaging can have a great impact on the overall environmental performance of a company, particularly through the consumption of resources, emissions and waste produced. Decisions on packaging require a well-thought-through decision to reduce the risk of transferring the environmental impact elsewhere in the supply chain. This thesis indirectly builds on two concepts that should be given more attention in research on sustainability and circularity topics, specifically in the context of sustainable industrial packaging and supply chain management. Even though the concepts have some overlaps, they complement each other in a meaningful way.

- **Integration –** coordinating activities and connecting them in a lean manner can be an effective strategy for efficient operations management. Integration can also be a mediator for robustness, which can (directly and indirectly) impact decisions on sustainable packaging as well as on supply chain management.

- **Collaboration –** from the design and development process to the material selection, the usage phase, and waste management, collaboration can efficiently integrate processes and activities throughout the packaging life cycle. There is a significant unexplored potential in collaboration between actors in the supply chain, that can even lead to "extending product value" and considering "industrial symbiosis" (e.g., European Cluster

Collaboration Platform [Casamada, 2021]). These are two circular economy strategies that can emerge from collaboration and integration, with great potential to reduce the environmental impact of packaging.

7.1.2. Contributions to practice

The studies presented and discussed have contributed to different industrial contexts and support managers to define the sustainability strategies for their businesses. As mentioned before, the studies consider the supply chain context in which the packaging is used. When referring to "supply chain context", this thesis focuses particularly on (1) the logistics system (particularly the impact of transport and activities in the warehouse), and (2) the entities that are (directly or indirectly) relevant in the context, particularly stakeholders or other partners (suppliers and service providers) and customers (other businesses [B2B] or customers [B2C]). Because the supply chain plays a significant role in how packaging is designed, used, and managed once delivered and turned into waste it should not be overlooked. Businesses should look carefully at the direct and indirect implications of packaging decisions, paying particular attention to how packaging design is affected during the packaging usage phase as well as during the EOL phase, and integrate those factors in the development process.

On a different research stream, this research contributes to the importance of a structured approach to companies when defining sustainability-oriented innovations. Without proper structuring and consideration of all the implications for in-house operations and the effects on the supply chain (both upstream and downstream), the likelihood of a successful (efficient and effective) implementation is reduced.

This research builds on two concepts that practitioners should explore as potential contributors in industrial packaging to improve (1) customer satisfaction (related to innovation management) and (2) sustainable business development (related to cost-benefit analysis).

- **Innovation management** – packaging's primary role is to enable the movement of goods; however, there are several opportunities that can improve the customer experience (it may be valid in B2C and B2B settings). Strategic packaging design and development can positively impact how a business is perceived in the market and help it stay competitive.
- **Cost-benefit analysis** – packaging can significantly affect customer satisfaction. An enhanced customer experience can drive the business growth and lead to larger market shares (or expansion into other market segments). It is, however, critical for the company to assess the cost-benefit of packaging logistics decisions and understand how the market is moving,

as well as how it may react to and perceive certain moves. Having that vision will free up resources to be invested and allocated to achieve a good return on investment.

7.1.3. Contributions to policies

On a similar note, the complexity of sustainability and supply chains can be difficult for policymakers to define and regulate how industry adjusts their green strategies. That is because the push in certain directions can be counterproductive and shift the environmental burden to some other activities or parts of the supply chain. This research brings up for discussion the challenges created with policies that steer industry in one direction (e.g., minimise emissions) as opposed to guide and motivate companies to introduce more "green" practices that are also more sustainable in the long-term.

When policymakers define targets for businesses to benchmark against, they make this specific metric a priority and not giving room to factor in the intricacies of the context in which it is being applied. Policies should therefore emphasise practices that are relevant regardless of the context. Three examples that are crucial for sustainable development and should be primary concerns for policymakers:

- **Prioritise local sourcing –** shortening supply chains is an efficient way to reduce the environmental impacts from transport. Reducing transport and handling also directly affects packaging design, as the risks of product damage are significantly lower, allowing for a reduction in the amount of packaging and/or the implementation of circular packaging solutions. Additionally, shorter supply chains enable closer collaborations and foster a stronger sense of common goal and integrated sustainable decision-making (Morgado, 2008).

- **Optimise resource flows (inputs and outputs) –** optimising processes and resource flows can significantly reduce the environmental impact of businesses. Instead of creating policies that lead companies to "mask" their less efficient processes by covering them up with metrics that do not actually improve efficiency, policymakers should encourage companies to enhance their environmental performance. This can be achieved by reducing the resources consumed per unit of service (material input per unit of service [MIPS] [Neto et al., 2017]) and by implementing lean principles and optimise outputs through continuous improvements (Amrina & Zagloel, 2019).

- **Ensure sustainable waste management –** pressuring companies to use more sustainable materials and ditch those with high ecotoxicity levels may

not be enough, and in fact risking creating some negative outcomes. Nevertheless, sustainable waste management needs to be ensured. While in-house waste management can be controlled, managing packaging waste that is generated elsewhere may require agreements between the actors. These agreements should be regulated to ensure that responsibility is assumed and accepted by one of the parties.

7.2. Limitations and future research

This section discusses the limitations of the research presented in this thesis followed by some research venues that should be explored further. In this subsection, only the limitations that are relevant to the insights that the thesis is trying to convey are discussed. This means that even though each of the papers have limitations on their own, if they are not found to be relevant on an aggregated basis, they are not discussed here. For that reason, two main limitations are brought forward to be discussed: first, the supply chain context and second the time frames.

This subsection splits into two segments. Firstly, explaining the limitation and zooming in into how the studies show those limitations (Section 7.2.1). Secondly, a brief discussion of the future research opportunities that should be explored (Section 7.2.2) and would contribute with relevant knowledge to overcome the limitations and gaps of this thesis.

7.2.1. Limitations

This thesis proposed to explore two supply chain contexts to discuss the different aspects that can impact sustainable industrial packaging decisions. Typically, B2B and B2C settings have different concerns and barriers to the implementation of sustainable practices with some of them being poked in the papers. However, one can always argue that the data on each of the contexts was limited and left out important aspects. In addition, the fact that only two case studies (B2B in **Paper II** and B2C in **Paper IV**) were investigated in this thesis does not allow one to deduce strong implications and thus, the findings cannot be generalised without careful considerations. This because, there is not enough data to analyse variables independently (isolated) and deduce the extension of the consequences of each and how that plays out overall (environmental and operations) performance. However, it is possible to draw conclusions on the aspects that caused the "problems" and highlight them, so they are considered as possible challenges in different contexts. In **Paper IV**, the sample of customers that took part in the field-test represents a niche market segment in Sweden. For that reason, it is fair to argue that different customers could have shown different levels of openness to trade a hassle-free

delivery for one that is more sustainable and circular but requires active participation. **Papers III** and **V** are based on the findings from the case studies and aim to infer theoretical conjecture to broader contexts, which can also be challenged.

As in all, research methods and methodologies can always be challenged and faulted. In addition to the limitations already discussed in each of the papers, one point that was less analysed was the impact of the time frame on which the analyses of the papers were based in **Papers II**, **IV** and **V** (**Paper I** was not limited by time in the search and in **Paper III** all available metrics and methods were tested with all available time frames). It should be acknowledged that different time frames could have changed some results. **Paper II** analyses the environmental impact of the packaging and logistics based on the impact on GWP100a. Even though this method is widely applied and recognised as "standard", one may argue that other time frames could have been more suitable for the study, particularly the ones focusing more on the long-term effects (500a or inf) – because of the long degradation times of plastics. **Paper IV** can also be challenged because on the time frame: the findings are based on a field-test in which 4 deliveries were conducted to test the circular model. While the less positive experience from the warehouse staff and the rather positive experience from the delivery drivers would be less likely to change over time, the experiences from the customers had changed more significant between the first and second interviews. This may suggest that the negative aspects were more of a concern than before. Thus, having a study with a longer time frame would have allowed for a better understanding of "how far" customers are willing to go to contribute to more sustainable models of deliveries. **Paper V** argues that sustainable-oriented innovations have the potential to increase businesses efficiency and thus competitive advantage. However, it is not possible to ground that in terms of time frames (short-, medium- and long-term) nor anchor it with empirical data.

7.2.2. Future research

To be able to find patterns and generalise results, more articles are necessary that explore similar dilemmas in different contexts. **Papers II** and **IV** contribute relevant findings and build on similar concepts from previous research studies. Yet, more research is needed to be able to find clearer patterns between contexts and to understand the intricacies between packaging and logistics in B2B and B2C contexts. Moreover, there is the potential to explore other sustainable models in which customers are involved, not only in e-commerce but also in traditional retail.

To build on the research presented in this thesis, there are other research venues with relevant contributions to the body of knowledge on the topic. Starting with the research conducted in the B2C settings, it would be interesting to explore more the real impacts of plastics in the longer term. Materials impact the environment in

different ways, and the time frame that is selected when conducting an LCA can significantly affect the results. Even though GWP100a is generally accepted as a good metric, there is a research gap regarding its suitability in assessing plastic waste. Regarding the studies on circular industrial packaging in B2B settings, it would be interesting to use the case study from **Paper IV** to conduct a Life-Cycle Analysis (LCA) and Life-Cycle Costing (LCC). These analyses would clarify the extent of the impacts and identify the activities that lead to more significant impacts and thus should be more carefully considered and/or replanned. Another research opportunity to build on **Paper IV** would be to conduct longer studies on customers' experiences and their disposition to be active participants in sustainable and circular supply chains. It is fair to say that customers' satisfaction decreased between the 2nd and the 4th round of deliveries, but one can only speculate about long-term expectations and perceived experiences. In **Paper V**, the proposed hypotheses should be tested with empirical data and in real-life contexts.

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