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Implementing a circular business model for reusable packaging: Multidisciplinary learnings from reusable pizza packaging

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ABSTRACT

This article explores practical challenges in developing and implementing circular business models in the context of reusable takeaway food packaging from a transdisciplinary perspective. It touches upon the desirability, feasibility, viability, and sustainability dimensions of a reusable pizza packaging circular business model. First, a literature review is conducted to highlight current knowledge and gaps around circular business models for reusable packaging and the key factors addressing the *desirability, feasibility, viability,* and *sustainability*. Second, a case study approach is taken for an in-depth exploration of these factors and their effect on the successful implementation of a reusable packaging business model. A real-life pilot is structured and implemented; questionnaire, workshops and semi-structured interviews with consumers and key stakeholders of the novel business model as well as technical laboratory tests of used packaging are used as key data sources in the case study. This study contributes to research and practice with a novel framework for circular business model innovation in the context of reusable packaging highlighting the need to iteratively address packaging as well as system conditions affecting the desirability, feasibility, sustainability, and viability of such ecosystem-based business models. Future research should inherently take a systemic perspective to address interconnections between these four dimensions and explore in which steps and order experimentations should be developed to balance trade-offs between feasibility and desirability while ensuring sustainability and viability of the business model.

1. Introduction

In a world grappling with pressing environmental challenges caused by human activity and civilisational megatrends (Lubowiecki-Vikuk et al., 2021), circular economy (CE) has been highlighted as an alternative paradigm to the current 'take-make-dispose' linear economy to help slow, close, and narrow resource loops and make better use of resources whilst addressing the growing concerns of resource depletion, waste generation and sustainability concerns (Geissdoerfer et al., 2017, 2020; Velenturf and Purnell, 2021). The transition to reusable packaging systems has been identified as a key strategy to tackle single-use plastic related waste generation and pollution (Bradley and Corsini, 2023; Johansen et al., 2022). Reusable packaging, characterized by its ability to be used multiple times, also stands out as a promising avenue to reduce the environmental impacts of packaging and their distribution networks (Tenhunen-Lunkka et al., 2023a). In 2019, widespread plastic use, inadequate disposal, and collection resulted in 22 million metric tons of plastic leaking into the environment causing persistent pollution. The leakage has more than doubled since 2000. (D'Amato et al., 2023) Persistent plastic pollution alters ecosystems, poses risks to human health and livelihoods, and incurs significant economic costs estimated at around 3000 €/tonne of marine plastic (Beaumont et al., 2019). Oceana analysed in their market study that 10 % increase in reusable packaging by 2030 can globally eliminate over 1 trillion single-use plastic bottles and cups, which would prevent up to 153 billion packaging entering the world's oceans and waterways (Oceana, 2023).

In the EU, on average, each person generates 35.9 kg of plastic packaging waste. The level of generated waste increases.; from 2020 to 2021, EU had a record-breaking increase of waste generation. In 2021 only, EU generated 84 million tonnes of packaging waste in total, of

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which plastic represents about 19 %. Between 2011 and 2021, the amount of plastic packaging waste generated per capita increased by 26,7 % (+7.6 kgs per capita). The amount of packaging used has increased faster than EU's economy and population. Even though recycling rates have increased, it is still not enough to keep up with the increase of the total amount of packaging waste generated. (Eurostat, 2023) Furthermore, it is reported by the European Commission that many member states are struggling to meet EU's recycling targets (Directorate-General for Environment, 2023). One of the causes is unrecyclable packaging due to improper collection, sorting, lack of infrastructure and processes. Leaked packaging waste typically ends up in the environment – about half of the marine litter consists of packaging. Also, the greenhouse gas (GHG) emissions from packaging total up to the emissions of a small to medium EU country. (European Council, 2024) This emphasizes the importance of reuse models where several packaging manufacturing and end-of-life management steps are avoided resulting in noticeable potential to reduce GHG emissions (Tenhunen-Lunkka et al., 2023b).

The need to reduce the generation on packaging waste is addressed in several EU legislation and strategy documents; furthermore, it is emphasized how waste reduction should be a priority over end-of-life management. For example, in the European Green Deal, Circular Economy Action Plan and especially in the currently under revision legislation on Packaging and Packaging Waste, where direct reuse targets would be implemented. According to the EU's waste priority hierarchy, reuse should be prioritised before recycling. (European Council, 2024) Due to the changes in the operational environment including demand from consumers, (Bradley and Corsini, 2023; Johansen et al., 2022) the importance of reusable packaging is increasingly being recognised and widely implemented at Business-to-Business (B2B) level, such as in transport packaging (Accorsi et al., 2020), but limited in Business-to-Consumer (B2C), such as retail environments (Coelho et al., 2020; Iacovidou et al., 2021).

Some knowledge exists for reusable food packaging implementation in B2C environments covering, for instance, environmental impact (Accorsi et al., 2020; Yadav et al., 2024), consumers' perceptions and behaviour (e.g., Ertz et al., 2017; Nicolau et al., 2022; Novoradovskaya et al., 2020), and circular business models (e.g., Bashir et al., 2020; Mollenkopf et al., 2005). However, the implementation of such reusable food packaging systems bears on challenges that require interdisciplinary and collaborative approaches among involved stakeholders (Iacovidou et al., 2021). For instance, business models are needed to engage consumers in food packaging while being technically feasible (e.g., safe), profitable and environmentally sustainable. Testing and gaining knowledge about the feasibility, desirability, and viability of circular business models can facilitate their implementation and scaling (Bocken et al., 2022), while assessing their sustainability potential from the outset can support their environmental value proposition (Manninen et al., 2018).

The purpose of this paper is to facilitate a holistic understanding regarding the introduction of a circular business model for reusable food packaging by bringing new knowledge on technical feasibility, consumer desirability, business viability and environmental sustainability (Fig. 1). By focusing on packaging reuse of takeaway pizza - a consumer product with presence in various countries - the paper combines empirical insights from four studies and existing literature to answer following research questions:

- Consumer desirability: What kind of changes in consumers' perceived value, and intentions with reusable packaging, and product (pizza) evaluation can be seen and what are the reasons behind value perception, intentions, and product evaluation? Are the value perceptions shared by general population?
- Business viability: What are the franchisees', restaurant managers' and staff's perceptions of reusable pizza packaging and perceived obstacles to make this business model feasible and desirable?

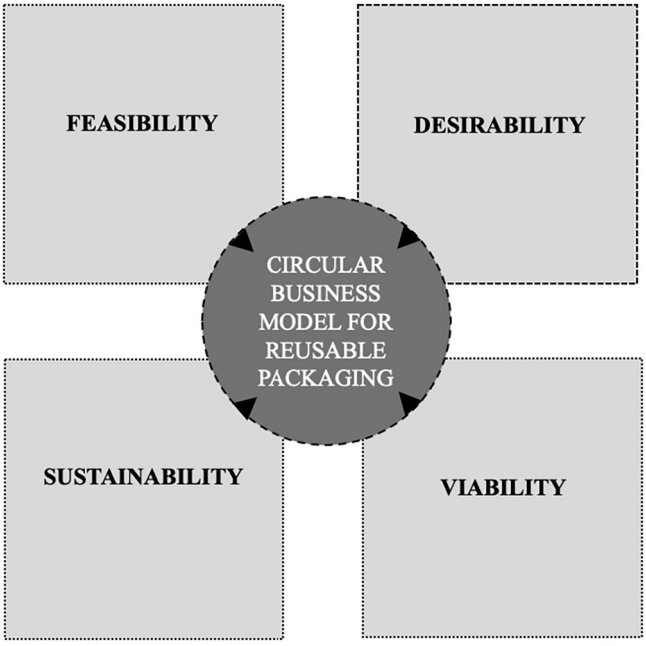

Fig. 1. Framing conditions for the implementation of circular business model for reusable packaging (Adapted from Bland and Osterwalder, 2019; Bocken et al., 2022).

- Environmental sustainability: What are the factors affecting the environmental sustainability in the case of the reusable takeaway pizza packaging according to the sustainability experts of the companies involved in the reusable takeaway pizza packaging pilot case?
- Technical feasibility: What is the relationship between packaging condition and wear from use in connection to the amount of packaging use cycles?

The paper is structured as follows; Chapter 2 reviews relevant literature on circular business models for reusable takeaway food packaging, focusing on dimensions in the focus of this study. Chapter 3 outlines methods and introduces the case study context. Chapter 4 provides results and presents the conceptual framework developed, while Chapter 5 discusses findings, and highlights contributions, implications, and future research areas. Chapter 6 presents the main conclusions.

2. Literature Review

The section provides an overview of the key concepts and earlier research, introduces circular business models in the context of reusable takeaway food packaging. It also examines the four dimensions affecting a circular business model implementation: consumer desirability, viability, technical feasibility, and environmental sustainability.

2.1. Circular Business Models in Reusable Packaging

Business model innovation describes the process of changing existing business models in established companies or designing entirely new business models in start-up companies to create, capture and deliver value in novel ways (Osterwalder and Pigneur, 2010). The core innovation is to make the shift from single-use packaging to reuse packaging schemes. The challenge lies in offering a novel business model that is feasible, desirable, and viable, while demonstrating its sustainability benefits (Tenhunen-Lunkka et al., 2023a). Well-performing business models are crucial to scale up reuse systems, yet, despite the growing interest of the private sector in the circular economy, the implementation of circular business models is still low in practice. Today, only few products with reusable packaging are available in the FMCG industry,

although a portfolio of new reusable packaging business models is emerging (Muranko et al., 2021). This shift requires new ways of designing and implementing business models (Santa-Maria et al., 2021) in which traditional roles of product manufacturers are reshaped. New service providers emerge, who are responsible not only for selling products but also take-back, refilling and reuse (Brown et al., 2019).

Introducing reusable packaging in the FMCG can take several forms. Specific typologies have been developed aiming at differentiating the structuration of such reusable systems (Coelho et al., 2020; Ellen MacArthur Foundation, 2019; Muranko et al., 2021; Tassell and Aurisicchio, 2020). Differentiation factors include the expected consumer behaviour (i.e., return or refill), the role of the provider, the location of reuse behaviour (at home, on the go), the ownership of the packaging, and the existence of an enabling infrastructure.

When designing and testing novel circular business models, four key dimensions need to be addressed: desirability, feasibility, viability, and sustainability (Bland and Osterwalder, 2019; Bocken et al., 2022). Desirability is a property of the value proposition: how desirable a value proposition is to the intended users. Feasibility is a property of value creation and delivery: how feasible it is to organize the needed activities and resources to create and deliver the value proposition. Viability is a property of value capture, it details how the business model can generate enough revenue to sustain the cost of creating and delivering the value proposition (Richardson, 2008). Lastly, three pillars of sustainability - environmental, social, and economic, form an integral dimension for circular and sustainable business models (Shakeel et al., 2020). Particularly, environmental sustainability is a property of the value proposition: how to reduce environmental impacts throughout the whole value chain (Manninen et al., 2018). In the following subsections, we synthetise current knowledge and challenges around these four dimensions in the context of reusable packaging business models.

2.2. Consumer Desirability of Reusable Packaging

In general, consumers seem to have mixed views towards the general idea of packaging reuse. On the upside, packaging reuse is seen as beneficial to environmental sustainability (Babader et al., 2016; Miao et al., 2023; Magnier and Gil-Pérez, 2023). For instance, Dutch consumers found the use of reusable packaging systems as contributing to the reduction of plastic packaging and related waste (Miao et al., 2023). Furthermore, consumers expect that reusable packaging is convenient and of quality (Bashir et al., 2020; Lofthouse et al., 2017; Lofthouse et al., 2009; Magnier and Gil-Pérez, 2023). For instance, the ease of transportation and delivery, lightness, bulkiness, fit-for-purpose, product safety, ease of functionality, additional time and space resources, packaging availability, risk of discontinuity, complexity, and compatibility were noted by UK consumers when evaluating the convenience of certain packaging refill products in home cleaning, personal care, and food categories (Lofthouse et al., 2009). Besides environmental sustainability value and certain exceptions, little is known about the value that consumers see in reusable packaging. Few indications from the literature point to the positive emotional and social meanings that reusable packaging may have for consumers. For instance, certain packaging refill types have been considered by consumers as “fun to use” and switching from single use to reusable packaging systems has increased consumers’ perceptions of their social value, as individuals (Lofthouse et al., 2017; Miao et al., 2023).

On a downside, consumers’ intentions, and willingness to reusable packaging seem to be low and vary between the packaging options indicating low desirability. For instance, a UK-based study (Greenwood et al., 2021) involving consumers’ evaluations of ninety commonly sold products in supermarkets (e.g., food, personal care, and home cleaning) showed that consumers were willing to return or refill only 12 % of them. According to the study, this was because consumers’ reuse behaviour is relatively habitual, and this translates into a willingness to return and refill products for which reuse systems already exist (e.g., milk in glass bottles) and reservation towards others (e.g., reuse of microwavable trays). Research further indicates that convenience and quality of reusable packaging are sources of concern for some consumers and influence their expectations of certain solutions. For example, products from several packaging refill schemes are expected to be cheaper than conventional solutions as it is generally thought that they cost less in terms of production and transportation. (Bashir et al., 2020; Lofthouse et al., 2017; Lofthouse et al., 2009).

Due to the early stage of modern reusable packaging solutions, the research on consumers’ desirability in reuse context is in its infancy and lacks systematic and holistic approaches to understand the topic. The concept of perceived value might be useful in gaining systematic view on reusable packaging desirability. Perceived value is defined as the “consumer’s overall assessment of the utility of a product based on perceptions of what is received and what is given” (Zeithaml, 1988, p. 14). The concept emphasizes that consumers evaluate an object (e.g., a product) from multiple dimensions, including functional, affective, and social components (Boksberger and Melsen, 2011), to reach their overall assessment. (Sweeney and Soutar, 2001) approach perceived value from the following four dimensions: 1) Functional value, referring to the perceived quality and expected performance of the product, 2) Emotional value, referring to the utility derived from the feelings or affective states that a product generates, 3) Price value, referring to the utility derived from the product due to the reduction of its perceived short term and longer-term costs and, 4) Social value, referring to the utility derived from the product’s ability to enhance social self-concept. In the context of reusable packaging, the importance of environmental sustainability value, indicating the utility derived from the expected contribution of the product to environmental sustainability, has been emphasized by many studies e.g. Babader et al., 2016; Bashir et al., 2020; Kunamaneni et al., 2019; Miao et al., 2023.

2.3. Business Viability of Reusable Packaging

Studies addressing business viability of reusable packaging are principally focusing on B2B business models (Mahmoudi and Parviziomran, 2020; Mollenkopf et al., 2005) while the B2C sector is understudied (Bocken et al., 2022; Li et al., 2023). Cost-analysis studies suggest that the overall costs of a reusable packaging system could be lower than that of single-use packaging, depending on a certain set of influencing factors (Schuermann and Woo, 2022). At logistics level, transport distances, cleaning costs, and labour involved greatly influence the cost-benefit equation (Accorsi et al., 2014; Coelho et al., 2020). From a service provider perspective, three key factors determine the level of value capture that can be generated: average rotation cycles before end of life (the number of times the packaging can circulate before being disposed of), return rates (percentage of packaging being returned after use) and retention time (number of days packaging is used before being returned). The three factors help determine the average use cycles which is detrimental to the value capture of the system (Willemijn et al., 2023).

Return rates vary between different systems and are positively affected by deposit fee systems (Coelho et al., 2020). Yet the acceptable amount of deposit fee and the preference of this approach as opposed to alternative approaches (fee-based approach if packaging not returned within a certain amount of days) is poorly understood. Beyond the willingness of consumers to be participating in the systems and thus capturing value for each additional cycle, business viability is also dependant on the capacity of internal stakeholders (e.g., staff, franchisees) to embrace the new business model and engage consumers in participating (Dada et al., 2023). This dimension is often understudied yet can significantly affect the potential value capture of the circular business model.

2.4. Technical Feasibility of Reusable Packaging

Shift from single use to reusable packaging creates specific technical challenges related to the reusable packaging due to increased amount of use cycles, handling, washing and other maintenance as well as refilling. This causes more wear on the reusable packaging. Understanding the abrasion resistance and material wear and scratching in reusable packaging has not been studied to much extent. As it is a key parameter that affects the lifespan of reusable packaging and its ability to be circulated, it should be the start of technical feasibility related reusable packaging material durability studies.

Plastic packaging are low-cost materials that are easily shaped into different shapes and formats. They are highly versatile and have high functionality, great barrier properties as well as high durability (Iacovidou et al., 2021; Tenhunen-Lunkka et al., 2023b). However, design efforts put into cost, performance, durability, and disposability have led to a failure to address end-of-life issues (Iacovidou et al., 2021). Moreover, additional requirements at system level affect the feasibility of new reusable packaging business models. These include reverse logistics, reuse-related operations, and maintenance like washing (with detergents) and/or cleaning, communication and marketing needs and possibly integration of intelligent elements such as sensors (Tenhunen-Lunkka et al., 2023a). The number of cycles the packaging can withstand is also an important determinant for the overall feasibility. According to Accorsi et al. (2020) and their study on reusable transport packaging, packaging's lifespan is a crucial factor when designing closed-loop systems and feasibility of reuse systems. The lifespan is typically measured in how many cycles a packaging can circulate and can be seen as a key parameter for packaging manufacturers to assess the profitability and long-term sustainability of the closed-loop system (Accorsi et al., 2020). The development of identity management and condition monitoring for reusable packaging is central for ensuring safe use, transparency, and maximizing their lifetime. Smart tags, visible or electronic markers with environmental sensing functions, coupled with software intelligence like machine vision, user information, and GPS, facilitate context-aware services through IoT connectivity. Smart tags play a vital role in enabling identity management and condition monitoring for reusable packaging. (Hakola et al., 2023).

Material wear, resistance to abrasion and overall scratching of the packaging is a key parameter that can in many ways affect the recirculation of the reusable packaging. Scratched packaging might not look visually appealing or feel safe to use, and it might be discarded during washing and maintenance. Scratching of plastics can be separated into indentation, which is caused by normal pressure on the surface, and sliding, which is caused by shear strain (Germann et al., 2022). For plastics, the nature of plastic deformation is found to correlate on the scratch direction and the deformation from scratching will change the number and arrangement of subsurface dislocations, which will result in change in the plastic strength or hardness (Gross et al., 2018; Ponce et al., 2009). In addition to the material behaviour, the scratching is heavily reliant on the indenter, or scratching, geometry, normal load and sliding velocity. In addition, factors such as the angle and temperature affect the types of damage the scratch will create (Germann et al., 2022). Scratches affects the optical material properties, which is why visibility of the scratches especially in reusable packaging applications is an important field to investigate. Scratch detection and the location of the scratch on the surface of reusable packaging is important in the quality control. Visual examination in good lighting conditions can be used to detect scratches and understand how consumers perceive the packaging, but also to choose points on packaging for further analysis to see finer scratches and their location with an optical microscope. Overall, the size, location and orientation of the scratch can offer further useful information in how material wear in multiple reuse cycles. (Gross et al., 2018).

2.5. Environmental Sustainability of Reusable Packaging

Although reusable food packaging can have positive environmental effects, as it extends the lifetime of food products and minimizes food waste, it also causes environmental impacts as it consumes materials, needs transportation, and involves end-of-life management (Coelho et al., 2020). Environmental impacts of the reusable food packaging are found in all phases of the packaging lifecycle. Therefore, when assessing the environmental sustainability of the reusable food packaging, the entire lifecycle of the packaging should be taken into consideration (Vignali, 2016). Looking at the environmental effects from the lifecycle perspective means considering the activities of different stakeholders involved in the business ecosystem in each of the lifecycle phase, and as stated by Fichter et al. (2023), sustainability impacts emerge via interactions with stakeholders.

Salo and Hylkilä (2023) have highlighted factors to be considered in each of the life cycle phase of reusable plastic packaging from the environmental sustainability point-of-view. In the design phase, the packaging should be fit for purpose but with as little amount of plastic/raw materials as possible. In the production and manufacturing phases the environmental effects are caused by the machinery used, the amount of water and energy consumption and used energy sources. The environmental effects of the use and reuse phases are dominated by the motivation and knowledge of the customers and end-users; are they willing to reuse the packaging and do it in a correct manner. In the collection phase, the main thing to be considered from the environmental sustainability point of view, is the amount of the collection points and their location from the customers' perspective. In the transportation phases, the way of transportation, the fuel choices, driving distances and driving routes are the main things to be considered from the environmental sustainability point of view. In the washing and refilling phase, the energy, water, and detergent usage are the key factors. In the end-of-life phase, the amount of reuse times and the chosen end-of-life management strategy, are the most important aspects. (Salo and Hylkilä, 2023).

Previous studies, e.g., Yadav et al. (2024), regarding the environmental sustainability of reusable food packaging have shown that the factors affecting the environmental sustainability are case specific and various. Some studies show that the largest environmental impacts are due to the washing of the reusable food packaging (e.g., Tua et al., 2019) while other studies emphasize the transportation of the reusable food packaging (e.g., Koskela et al., 2014; Levi et al., 2011). A 2023 report from Zero Waste Europe underscores the significance of transparent methodology and accurate assumptions in assessing the true potential of reusable take-away packaging (Hann, 2023). In the midst of contradictory Life Cycle Assessment (LCA) results comparing single-use and reusable packaging, LCA scientists were prompted to caution EU policymakers about possible major impact of even minor assumptions on LCA results (Bala et al., 2023).

Most of the previous studies regarding environmental sustainability impacts of reusable packaging are done from the perspective of incumbent companies and their existing products or services (e.g., Fichter and Clausen, 2013; Strömmer and Ormiston, 2022). In these studies, the main research method used is mostly LCA based on existing data. However, studies that are conducted from the perspective of early-stage companies or from the perspective of new business model introduction are minor in the literature, as little environmental data is available prior to implementation. Thus, future-oriented perspectives studying the potential environmental impact of future reusable packaging systems are essential when designing circular business models.

3. Methods

The overall process carried out in terms of methodology is presented in Fig. 2. In conducting the literature review for the scientific article, a comprehensive methodology was applied to ensure the thorough

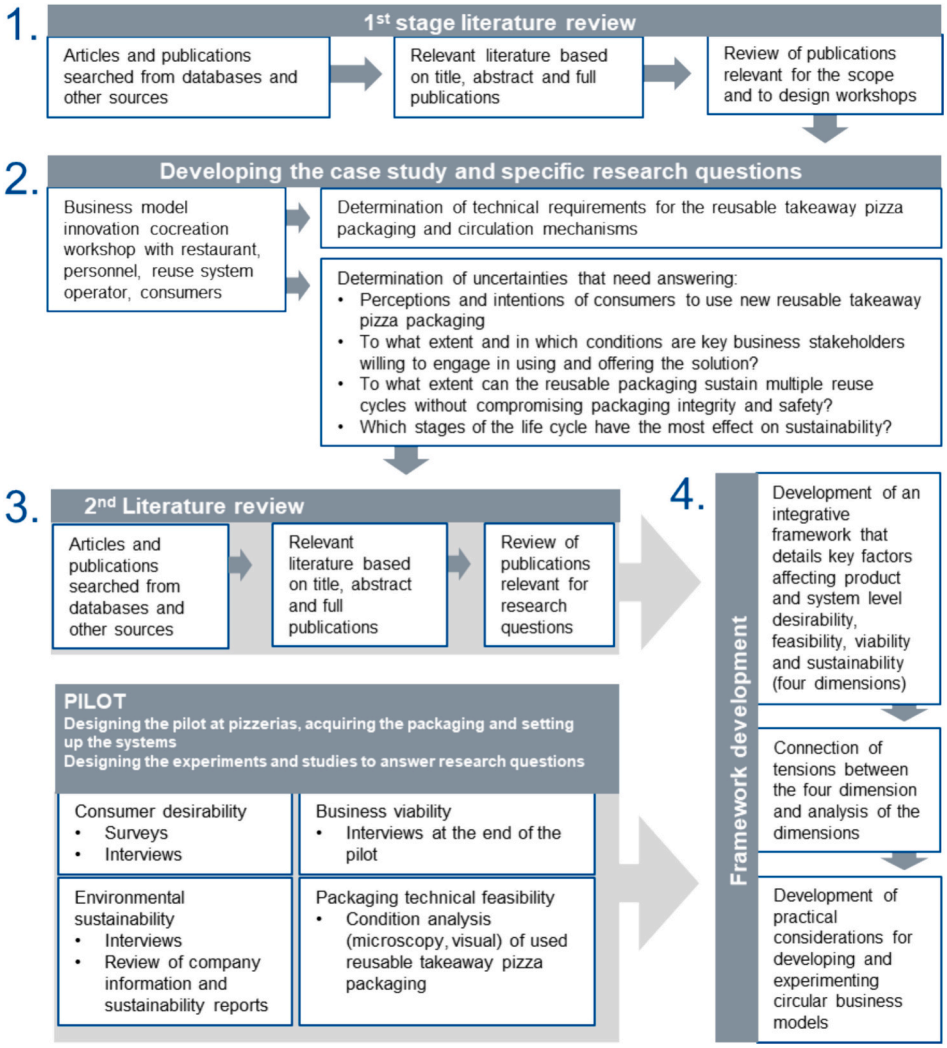

Fig. 2. Illustration of the logical process of the research conducted.

examination of existing research relevant to the study. Initially, key databases and sources, including academic journals, conference proceedings, and reputable online repositories (Elsevier Scopus, Zenodo, Google Scholar) and abstract and citation database Scopus, were identified. Utilizing a systematic search strategy, a combination of keywords developed with the pilot stakeholders was used to refine searches and capture the most pertinent literature. Additionally, inclusion and exclusion criteria were utilized to ensure the selection of studies aligned with the research objectives.

The following types of keywords were used: reusable food packaging, reusable packaging, reusable takeaway packaging, reusable pizza packaging, reusable pizza packaging, packaging; and they were combined with key words relating to the four dimensions: business viability, business desirability, economic assessment, economic analysis, economics, cost-effectiveness, pilot, case study, consumer preference, consumer demand, consumer perception, consumer study, consumer behaviour, social behaviour, sustainability, environmental impact, environmental assessment, LCA, sustainability assessment, carbon footprint, sustainable development, food safety, packaging materials, design, ecodesign, plastic durability, plastic scratching, material development, scratch resistance, durability, scratching, circular economy, reuse, conceptual framework, barriers, challenges, gap. Comparisons between single-use and reuse packaging were included, but studies focusing solely on single-use packaging without considering reusable alternatives were excluded. Non-peer reviewed literature and studies that were significantly outdated and not reflective of current trends or technologies in reusable food packaging were not prioritised but included if felt relevant by the topic.

Following the retrieval of relevant articles, 1st stage screening and evaluation were undertaken for quality and relevance, synthesizing key findings, and identifying gaps in the literature. A robust foundation was created to be used for stakeholder workshops organised to design and develop the pizza case study and specific research questions to be studied in the pilot.

Four main topics were covered relating to the reusable takeaway pizza packaging: consumer desirability, packaging technical feasibility, product environmental sustainability, and product business viability. Different methodologies were applied to investigate formed research questions (as summarised in Table 1). The outcomes of the pilot coupled with the literature reviews formed the basis of a comprehensive framework that was developed to help identify practical considerations when developing and experimenting circular business models.

Table 1 presents the aims, methods and data related to the pilot study, arranged according to the four dimensions which are critical for the implementation of circular business models in the context of reusable FMCG packaging. Seeds for each of the aims and related research questions emerged during the three exploratory business model innovation workshops (Section 3.1). These were refined further by all pilot partners at the planning phases of the pilot.

The methodology chapter first describes the reasoning behind

Table 1
Overall and individual aims, methods and data produced in relation the research carried out.

	Aim	Method	Data
Consumer desirability	To study what kind and to which extent consumers associate value in reusable takeaway packaging.	a) Repeated short online survey in the beginning and at the end of the pilot. b) In-depth interviews with selected participants at the end of pilot. c) Online survey among Finnish, UK, and German consumers	a) 33 survey responses b) 12 interviews c) 2400 responses to online survey (800 per country)
Business Feasibility and desirability	To study practitioners' perceived obstacles and opportunities to make business model for reusable takeaway pizza packaging feasible and desirable.	In-depth interviews with a selection of franchisees, and restaurant managers, as well as an online survey with staff in restaurants where the pizza packaging was tested.	5 interviews and 18 survey responses
Environmental sustainability	To study the factors affecting the environmental sustainability in the case of the reusable takeaway pizza packaging from the viewpoint of the companies involved in the reusable takeaway pizza packaging pilot case	Primary data from in-depth interviews with sustainability experts of the two companies involved in the reusable takeaway pizza packaging pilot case. Secondary data from websites and sustainability reports of the companies involved in the case	2 interviews with the sustainability experts of the companies involved in the reusable takeaway pizza packaging pilot case and public data from the company websites/ sustainability reports of those companies to gain background information for the interviews
Packaging technical feasibility	To study how the condition of reusable takeaway pizza packaging is influenced by reuse cycles.	Analyse the condition of used reusable takeaway pizza packaging from the pilots via optical microscopy and compare the scratched vs unscratched surfaces.	Naked-eye condition analysis, microscopic analysis, and relative scratching area analysis of 12 pizza packaging.

choosing a single case study (3.1), introduces the context and nature of the case study (3.2), and details the complementary methods used (3.3) to reach our objectives.

3.1. Case Selection

The aim of this study is to explore factors which are critical for the successful implementation of a circular business model for reusable food packaging, namely desirability, viability, environmental sustainability, and feasibility. To meet that objective, we perform an in-depth single case study, following Yin's definition*: "A case study is an empirical inquiry that investigates a contemporary phenomenon within its real-life context, especially when the boundaries between object of study and context are not clearly evident."* (Yin, 2014, p. 19). Based on the literature review, the learnings from reusable packaging field pilots are scarce and poorly documented in academic publications. By studying a single-use case, one can create a deeper understanding of the explored subject (Gustafsson, 2017) as well as explore a certain setting to understand it better (Cousin, 2005; Creswell and Poth, 2017).

The case context is a takeaway food company selling pizza in reusable pizza packaging. This study's *inquiry* focuses on the practical challenges and influencing factors leading to the implementation of a circular business model for reusable pizza packaging. Case study methodology fits the aim of this study since we need to understand contextual factors in practice, which can help identify conditions leading to successful implementation of the new business model. By focusing on single case, it offers an opportunity to deep dive into the context and ensure sufficient understanding of such contextual factors.

Circular business models related to reusable packaging were explored during a public research project, 4everPack, aiming to develop new market opportunities for Finnish companies in sustainable FMCG packaging (June 2021–September 2023). A case study for reusable pizza packaging was developed in the project among different use cases. As the key actors of a future ecosystem were actively involved in the research project, and the use of a potential packaging prototype provider had been identified, the pizza packaging case study became relevant to investigate further.

Critical conceptualisations of the novel business model were identified through a series (3) of business model innovation cocreation workshops (spring 2022) during which the key role of stakeholders (restaurant and restaurant personnel, reuse system operator, consumers) as well as the technical requirements of the reusable takeaway pizza packaging and its circulation mechanisms were identified. The three online workshops lasted 2 h each and involved 15 participants from two research organisations and 7 company representatives foreseen to have an active role in the future ecosystem – material providers, packaging provider, restaurant franchisor, IT providers, and reuse operator. Specific templates and canvases were used in an online environment (Miro board) to visualise and characterise the future solution from a network (actors, roles, activities) and a user perspective (value proposition, user journey).

The outcomes of the workshops allowed to characterise some initial value creation and delivery mechanisms, including technical requirements, the choice of packaging, the tracking solution, the role of franchisees in the reuse processes (washing, storing) and the financial mechanisms (fee per use). The tracking, collection, sorting, washing, and redistribution were able to be organised by the ecosystem actors and would not be the bottlenecks for orchestrating the pilot. More importantly, a set of key uncertainties that should be explored further though real-life experiments were identified:

- Consumer desirability: what are the perceptions and intention to use new reusable takeaway pizza packaging? Will these perceptions change over time? What explains the perceptions? How do broader consumer populations view the idea of reusable pizza packaging?
- Business viability: to what extent and under which conditions would key business stakeholders be willing to engage in using and offering such solution?
- Technical feasibility: to what extent can the developed reusable takeaway pizza packaging sustain multiple reuse cycles without compromising the material and packaging integrity?
- Environmental sustainability: which stage of the life cycle of the solution have the most effect on environmental sustainability?

Since existing empirical knowledge for each of the above-mentioned topics was little or non-existent, a decision among interested partners was reached to conduct a small-scale real-life pilot.

3.2. Case Description: Reusable Pizza Packaging

The case involved the largest pizza restaurant franchisor in Finland, a

reusable packaging system operator, VTT Technical Research Centre of Finland and the University of Vaasa. The franchisor operates a chain of pizza franchises, which counts for over 300 restaurants in Finland. The franchisor participated in the pilot by introducing a reusable packaging for takeaway pizzas to six restaurants with the aim to gain new knowledge from the consumers' and franchisees' points of view as well as exploring more concretely sustainability and feasibility dimensions. The reusable packaging system operator offered reusable packaging solutions through a system consisting of reusable takeaway pizza packaging prototype, a digital deposit and borrow system as well as environmental impact data. The reusable packaging used in the pilot was sourced from a reusable pizza packaging start-up, offering a reusable polypropylene (PP) pizza packaging (Fig. 3). The consumers returned the boxes back to the restaurant, the restaurant washed, sorted, and redistributed the packaging. University of Vaasa and VTT supported the pilot by facilitating business model experimentation workshops, collecting data about consumers, business operations, sustainability management, in collaboration with the franchisor, and carried out laboratory experiments.

The pilot was implemented in six different locations across Finland: Lapua, Lappeenranta, Oulu, Helsinki, Jyväskylä, and Järvenpää for a 2-months period. The reusable takeaway pizza packaging underwent testing by 40 members of the franchisor's loyalty program. In one of the locations (Jyväskylä) the reusable takeaway pizza packaging was available to any interested customer through a deposit-based scheme (6 € per packaging) during the pilot period. The 40 pilot participants were recruited by the franchisor based on: 1) earlier expressed interest to participate in research regarding reusable packaging, and 2) residential area, as reusable packaging was available at the above-mentioned locations. Each recruited participant was provided with an information sheet related to the use of the reusable takeaway pizza packaging and a voucher worth of 30 €, which could be redeemed during the test period for the purchase of pizza in a reusable packaging.

3.3. Data Collection and Analysis

From a consumer desirability perspective, the research aimed to gather consumer insights on perceived value of the reusable pizza packaging, intentions to use the piloted solution in the future, and product evaluations. In addition, reasons behind the value perceptions, intentions, and product evaluations were collected. From a viability perspective, researchers and the franchisor decided to focus on the perception of internal actors (e.g., franchisees and their staff), as a negative "buy-in" of the solution would mean a halt of the business model innovation process, even before considering costs and revenues formulas. From the environmental sustainability perspective, the study focused on identifying the main factors that could impact the sustainability of the future solution throughout its lifecycle. From a technical feasibility perspective, the durability feature of the packaging throughout multiple cycles was explored by addressing the amount and depth of scratches throughout multiple uses.

3.3.1. Consumer Desirability

During pilot, consumer desirability was studied through a short online survey in two points of time. The reason for this approach was to find answers to the question about changes in perceptions over time identified at the case selection stage (Section 3.1). The first survey was implemented right after the participants' first purchase of pizza in reusable packaging to gain their initial impressions with the packaging and the product. The second survey was administered at the end of the pilot period (2–3 pizzas bought and consumed per participant, approximately 2 months after the first exposure to the packaging) to understand how repeated use of the packaging influences the perceptions. In addition, interviews with 12 participants were conducted after the pilot to explore the reasons behind the survey results. The franchisor invited participants - who had shown interest in participating - to the pilot by sending a link to the survey form via a text message. By following the link, participants were provided with information about the study purpose and instructions, the responsible organization carrying out the

Fig. 3. The reusable pizza packaging used in the pilot

study, the funding body, the project that the study was linked to, data handling procedures, estimated answering time and a link to data protection statement. When answering the survey, participants did not share personal or other data potentially compromising their individual participant identity. The study design was approved by the ethics committee for Human Sciences of University of Vaasa (294/00.10.01/2022, approval date 27.10.2022).

The sample characteristics for the survey and interviews are depicted in Table 2 below. Initially, 40 participants were recruited to the survey resulting in seven dropouts and 33 (82.5 %) participants finishing both surveys. The survey sample consisted of 15 males and 18 females with participants in age groups ranging from 18 to 25 to 56–65. In the interviews, the sample was balanced between males (6) and females (6). Participants from the same age groups as in the survey were present in the sample.

The survey instrument was similar in both surveys capturing four dimensions of perceived value (functional, social, emotional, and environmental) (survey instruments reported in S1.1 and S1.2). Each value dimension was measured with two items on a 5-point Likert scale ranging from 1 = totally disagree to 5 = totally agree. Scales for the functional (Cronbach $\alpha_{survey1} = 0.50$; $\alpha_{survey2} = 0.57$), emotional (Cronbach $\alpha_{survey1} = 0.81$; $\alpha_{survey2} = 0.93$), and social value (Cronbach $\alpha_{survey1} = 0.61$; $\alpha_{survey2} = 0.53$) were adopted from Walsh et al. (2014). Items for the environmental value (Cronbach $\alpha_{survey1} = 0.95$; $\alpha_{survey2} = 0.81$) were developed for the purposes of this study following Koenig-Lewis et al. (2014). Intentions towards the reusable takeaway pizza packaging (Cronbach $\alpha_{survey1} = 0.95$; $\alpha_{survey2} = 0.95$) were measured with three items and similar Likert scale as perceived value adapted from Zerbini et al. (2019). Product evaluation scale included six single-items (*pizza odour, appearance, crispiness, temperature, taste, and overall pleasantness*) measured with 5-point Likert scale ranging from 1 = extremely unpleasant to 5 = extremely pleasant.

At the end of the pilot period, interviews lasting approximately 30 min were conducted online or over the phone with 12 volunteering participants to understand reasons behind the survey responses (Interview protocol reported in S1.3). The themes covered in the interviews were general impressions and use-related experiences with the reusable packaging (e.g., storing, cleaning, returning), any noticed differences in eating pizza from reusable packaging in comparison to conventional packaging (i.e., made from cardboard) and their intentions to use reusable packaging for take away pizzas in the future.

In addition to the surveys and interviews carried out during the experiment, a larger scale online survey was implemented in Finland, UK, and Germany to gain understanding on larger consumer population value perceptions and intentions towards reusable take-away pizza packaging (survey instrument reported in S1.4). In each country, 800 consumers responded to the survey administered by an external service provider totalling to 2400 participants. The online survey was approved by the ethics committee for Human Sciences of University of Vaasa (294/00.10.01/2022, approval date 27.10.2022). Table 3 presents the sample characteristics.

In the beginning of the online survey, the participants were presented with a written description of reusable packaging for take-away pizza. The description read: "*A take-away pizza is bought in a reusable packaging at a pizza restaurant. The reusable packaging is returned to the restaurant in the next visit. Reusable packaging for take-away pizzas are used multiple times. Between the uses, the packaging is cleaned and put back to use*." After reading the narrative, they were asked to evaluate the concept from the perceived value and intention perspectives. Same scales and items for perceived value and intentions were used as in the field experiment with the exception that functional value was measured with three items. In addition, the tone of the items was conditional as the participants were expected not to have previous experience with reusable pizza packaging. For the analyses, aggregate variables were formed with sufficient internal consistency: functional value (Cronbach $\alpha_{Finland} = 0.88$; Cronbach $\alpha_{UK} = 0.86$, Cronbach $\alpha_{Germany} = 0.80$), environmental value (Cronbach $\alpha_{Finland} = 0.89$; Cronbach $\alpha_{UK} = 0.85$, Cronbach $\alpha_{Germany} = 0.86$), social value (Cronbach $\alpha_{Finland} = 0.88$; Cronbach $\alpha_{UK} = 0.88$, Cronbach $\alpha_{Germany} = 0.82$), emotional value (Cronbach $\alpha_{Finland} = 0.92$; Cronbach $\alpha_{UK} = 0.88$, Cronbach $\alpha_{Germany} = 0.88$), and intentions (Cronbach $\alpha_{Finland} = 0.95$; Cronbach $\alpha_{UK} = 0.93$, Cronbach $\alpha_{Germany} = 0.94$). The survey instrument was originally developed in English and then back-translated to Finnish and German.

Both field experiment and online survey data were analysed with IBM SPSS software (version 28, IBM Corp, Chicago, IL). Before deciding on the exact analysis method, the distributions of perceived value and intention measures were checked with Shapiro-Wilk test for field experiment and Kolmogorov-Smirnov test for online survey. The results showed that none of the measures followed normal distribution ($p < .05$). Therefore, Wilcoxon signed-rank test was applied for the field experiment (test results reported in Subsections 4.1.1 & 4.1.2). This method is also feasible for the single-item ordinal scale measures used for product evaluation.

Kruskal-Wallis test was applied for the cross-country online survey to detect potential country-wise differences (test results reported in Subsection 4.1.4). For the interview data, standard content analysis was applied to classify the insights to form a view on the reasons behind participants' value perceptions, intentions, and product evaluations (interview findings reported in Subsection 4.1.3).

3.3.2. Business Desirability and Feasibility

As internal stakeholders' buy-in is a pre-condition to the business viability of the solution, the research focused on restaurant employees' and managers' perspectives on reusable pizza packaging and its overall system. In that respect, two online surveys (S2) and semi-structured interviews (S3) were conducted in February and March 2023. The online surveys were targeted to restaurant employees working on those six restaurants participating in the pilot, while the semi-structured interviews were conducted with restaurant franchisees and managers. The first survey was conducted with general questions on usability, benefits, and disadvantages in using and offering reusable takeaway pizza packaging to customers. The second survey contained additional questions on a deposit model and was targeted to one restaurant, which piloted also deposit models. In total, 18 staff members participated in the online surveys, 14 in the first survey and four in the latter. On average, a restaurant of the pizza franchisor has approximately seven employees, making the response rate over 40 %. Furthermore, five individuals in managerial positions were interviewed, including three franchisees, a restaurant manager, and a director of restaurant management. The interviews were conducted through phone calls and were recorded. The length of interviews ranged from 21 to 36 min, with an average of 28 min. The thematic interviews focused on managers' and franchises' views on motivational aspects, expectations, and perceived benefits regarding the uptake of reusable takeaway pizza packaging, as well as key challenges identified during the pilot. Qualitative content analysis was used as a main method to analyse the survey and interview data.

Table 2
Sample description of the survey and interviews.

	Survey (N = 33)	Interviews (*N* = 12)
Gender (%)		
Male	15 (42.5)	6 (50)
Female	18 (54.5)	6 (50)
Other/I do not want to say	1 (3)	
Age groups (%)		
18–25	9 (27.3)	4 (33.3)
26–35	9 (27.3)	3 (25)
36–45	6 (18.2)	1 (8.3)
46–55	7 (21.1)	3 (25)
56–65	2 (6.1)	1 (8.3)

Table 3
Characteristics of the Finnish, UK and German samples by gender, age group, education, self-reported income, and place of residence. Significant differences between the countries are denoted with different superscript letters.

Sample characteristics (%)	Finland ($N = 800$)	UK ($N = 800$)	Germany ($N = 800$)	Total ($N = 2400$)	*Chi-square*	*df*	*p*
Gender					7.366	4	0.118
Female	52.3[a]	50.6[a]	51.2[a]	51.4			
Male	47.4[a]	48.6[a]	48.8[a]	48.3			
Other	0.3[a,b]	0.8[b]	0.0[a]	0.3			
Age group					51.430	6	<0.001
18–35	28.1[a,b]	29.5[b]	24.0[a]	27.2			
36–50	22.4[a]	30.0[b]	27.9[b]	26.8			
51–64	19.1[a]	16.8[a]	27.1[b]	21.0			
65+	30.4[a]	23.7[b]	21.0[b]	25.0			
Education					79.522	6	<0.001
Higher education	49.6[a]	65.3[b]	54.8[a]	56.6			
Secondary education	39.4[a]	26.9[b]	41.3[a]	35.8			
Compulsory education	10.4[a]	6.4[b]	3.5[c]	6.8			
Something else	0.6[a]	1.4[a]	0.4[a]	0.8			
Self-reported income					33.380	4	<0.001
High income	2.8[a]	3.3[a]	6.3[b]	4.1			
Middle income	54.2[a]	57.7[a,b]	62.3[b]	58.1			
Low income	43.0[a]	39.0[a]	31.4[b]	37.8			
Residence					79.641	4	<0.001
Capital	22.9[a]	17.8[b]	20.0[a,b]	20.2			
Other urban area	57.8[a]	58.2[a]	42.9[b]	53.0			
Rural area	19.3[a]	24.0[a]	37.1[b]	26.8			

3.3.3. Environmental Sustainability

The environmental sustainability of reusable takeaway pizza packaging was assessed from a future-oriented perspective concentrating on a real-life pilot case study that is still in the design and development phase instead of an existing commercial solution. Therefore, there was no existing data of the reusable takeaway pizza packaging from any lifecycle stages and no existing system the pizza packaging would circle in. For that reason, LCA calculations were not a feasible option to enforce. We believe that the future-oriented LCAs conducted based on hypothetical data from open sources do not correspond to the actual pilot case. There are previous studies supporting our decision by showing the importance of accurate and scrutinized data to conduct reliable LCAs. According to Ayres (1995) and Curran (2014), the process descriptions and numeric data required to accomplish the LCAs from open sources may not address the actual practice (Ayres, 1995; Curran, 2014). A more recent report written by Hann and published by Zero Waste Europe (2023) based on three LCA studies done on reusable packaging in the take-away sector highlight the importance of reliable data by showing that importance of transparent methodology and accurate assumptions are crucial in understanding the true potential of reusable take-away packaging (Hann, 2023). LCA scientists have even written an open letter that urge EU policy makers to treat packaging environmental impact assessments with caution due to the fact that small variations in assumptions can completely change the LCA results and undermine the applicability of an LCA (Bala et al., 2023).

Instead of conducting LCAs based on hypothetical data, semi-structured interviews with sustainability experts from companies involved in the reusable takeaway pizza packaging pilot case (As exhibited in S4) were conducted to gain understanding on the factors the sustainability experts perceive to affect environmental sustainability of the reusable pizza packaging throughout their lifecycle. The sustainability managers were chosen as the interviewees since their responsibility is to evaluate the impacts of the operations their companies conduct on the environment and look for ways to make the business and solutions more sustainable. The interviewed sustainability experts were from a company that is developing and offering reusable takeaway pizza packaging to their customers (B2B) and a company that is piloting and experimenting the reusable takeaway pizza packaging in their restaurants and offering them to their customers (B2C). The interviews took place during January and February 2023. Besides interviewing the two sustainability experts, the websites of the companies involved in the reusable takeaway pizza packaging pilot and their sustainability reports were used as a secondary data to gain background information for the interviews. The interview questions and themes were related to the motivation of the companies to develop or test the reusable takeaway pizza packaging, the steps and activities the packages face during their lifecycle and the environmental effects first lifecycle phase by phase and second by how great or minor the environmental effects are based on the opinions and knowledge of the interviewees. Based on the interviews and additional data gained from the company websites and sustainability reports, the factors that affect the environmental sustainability of reusable takeaway pizza packaging throughout their lifecycle, were identified.

3.3.4. Technical Feasibility

In the workshops, it was identified that the tracking, collection, sorting, washing, and redistribution could be handled with the partners involved and did not form as bottlenecks for the pilot. The reusable packaging operator was involved, who offered the QR code and their system for tracking. The consumers returned the boxes to the restaurant, which is also the business model of the reusable packaging operator, the restaurant washed and redistributed the packaging. Major uncertainties for the businesses were how the reusable pizza box would function and sustain the operations at the restaurant and the use of the consumers. The technical feasibility of the reusable takeaway pizza packaging aimed to evaluate whether the reusable takeaway pizza packaging can meet required performance and be effectively integrated in the circular business model to replace single-use packaging. This was done by studying the condition of the packaging in relation to the use cycles.

For the condition analysis, a selection of unused and used reusable pizza packaging were acquired after the pilots at the franchisor restaurants. Each packaging consists of a base and a lid, which are identical pieces (Fig. 3). Each base has a QR-code than can be matched with data set telling how many times the has been used. The lids were not marked for the pilots. A representative group of different use cycles was chosen and cycles 0, 1, 2, 3 and 4 were chosen (4 cycles being the maximum cycles that could be acquired from the pilot), where most worn or most scratched as well as least worn samples were chosen. The aim was to investigate the condition of them after the use in the pilots, overall appearance of the packaging and how using them has affected their appearance. Altogether, 12 packaging basis or lids were chosen for further investigation. Investigation of the condition was done in the

following steps: selected packaging, basis, and lids were photographed to document their overall condition and a short condition analysis was written. The aim was to use this type of data to analyse and gain understanding what the condition looks like to the naked eye and how scratches and wear marks are located within the packaging. After this, detailed microscopic analysis of three most remarkable scratching spots were done. From the microscopic images, insights on scratch behaviour and surface modification were documented and the relative share of scratches and unscratched surface was calculated. Data analysis was done by microscopic image calculation with ImageView software. More specific settings of the microscopic analysis and microscopic image calculation are presented in S5.

For the technical experiments, protocols for maintaining consistency and minimizing conditions and variables that can affect the end results were followed. The packaging was stored and handled carefully not to cause any scratching from the experimental phase. Clear and thorough documentation of the packaging, experimental conditions and data collection was implemented. A detailed documentation of the inspections and measurements were documented.

4. Results

First, the outcomes of each individual enquiry within the pilot are described. Second, a conceptual framework integrating the results is introduced.

4.1. Consumer Desirability of Reusable Pizza Packaging

4.1.1. Perceived Value and Intentions towards Reusable Pizza Packaging in Field Experiment

The results for the participants' value perceptions are reported in Fig. 4 below, based on the Wilcoxon signed-rank test. In general, each dimension of measured perceived values exceeded the mid-point of the scale, the highest being perceived functional and environmental value. No differences between the two data collection points emerged (functional value ($Z = -1.156$, $p = .25$), environmental value ($Z = -1.253$, $p = .21$), social value ($Z = -1.460$, $p = .14$), emotional value ($Z = -1.611$, $p = .11$).

The descriptive results show that participants' intentions to use the reusable pizza packaging scored around four on a five-point scale in both data collection points (Fig. 5). However, the intentions were lower after the pilot period ended than after picking the pizza for the first time ($Z = -3.103$, $p = .002$).

4.1.2. Product Evaluation in Field Experiment

The Wilcoxon signed-rank test results for product evaluation in both data points are reported in Fig. 6. Overall, the evaluations were relatively high reaching over four on a five-point scale for all measured aspects except for the perceived temperature of the pizza. No differences between the two data points emerged in pizza odour ($Z = -0.024$, $p = .98$), appearance ($Z = -1.209$, $p = .23$), crispiness ($Z = -0.428$, $p = .67$), temperature ($Z = -0.449$, $p = .65$), and overall pleasantness ($Z = -0.218$, $p = .83$). In perceived taste, the evaluations were lower at the end of the pilot ($Z = -2.500$, $p = .01$).

4.1.3. Reasons behind participants' Evaluations

The interviews with 12 selected participants were for achieving additional understanding on the reasons behind value perception, intentions, and product evaluations. As a general observation, during the interviews, participants expressed their views regarding the reusable takeaway pizza packaging by often contrasting their experiences with traditional cardboard take-away packaging. When focusing on the relevant topics of the study, in terms of *functional value*, durability, shape, external temperature, and storage of the reusable packaging and pizza serving seem to influence consumers' perceptions of its performance and quality. For instance, the lid of the reusable takeaway pizza packaging was appreciated as it did not touch the pizza's toppings, and thus protected the condition of the pizza. On the other hand, the external temperature was positively and negatively described, such as "neutral", "pleasant" but also as "burning hot". Storing the packaging(es) at home felt burdensome for those living in small apartments and for families. Finally, the serving of takeaway pizzas from the reusable pizza packaging posed several challenges. For instance, the pizza was not pre-cut by the restaurant's personnel, consumers were instructed to remove the pizza from the packaging before cutting it. Such way of serving was identified as a challenge since it required consumers to have available plates of appropriate size and created more dirty dishes and extra dish washing.

Explanations reflecting *social value* emerged. Packaging design and branding may influence the way(s) that consumers with reusable pizza packaging are perceived by others around them. Some participants noted that the unusual design of the packaging raised interest among other people. Moreover, the presence of logos, pictures and patterns would contribute to the branding of the packaging. One interviewee stated:

> "But of course, when it will be on that point that it is launched properly and there will be put all logos and such, and is nicely

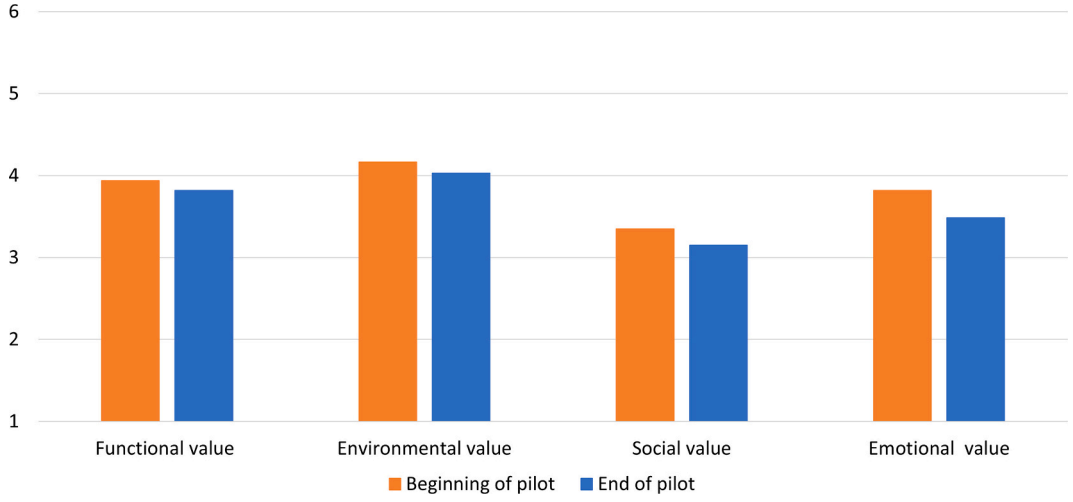

Fig. 4. Perceived value of reusable take-away pizza packaging in the beginning and at the end of the pilot. Bars represent means. Significant differences in main effects are denoted with different superscript letters. Scale from 1 = Totally disagree, 5 = Totally agree.

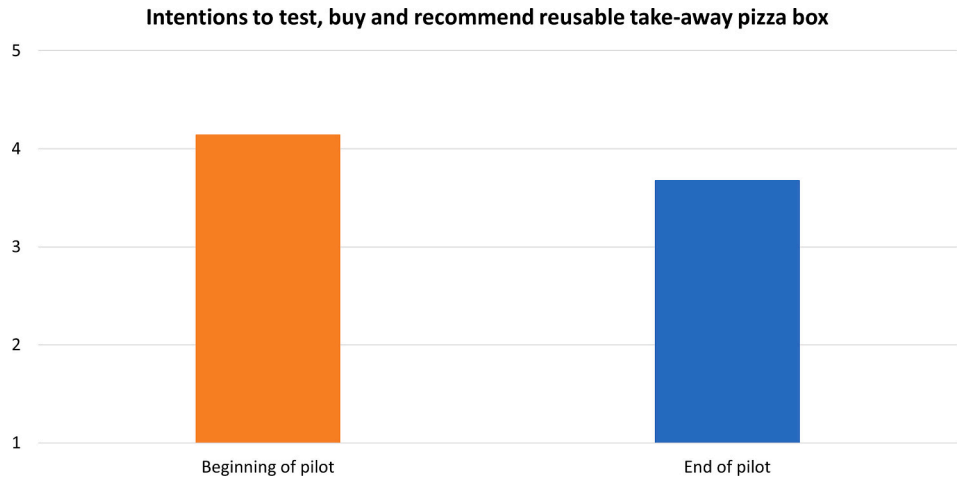

Fig. 5. Intentions to test, buy and recommend reusable take-away pizza packaging in the beginning and at the end of the pilot. Bars represent means. Significant differences in main effects are denoted with different superscript letters. Scale from 1 = Totally disagree, 5 = Totally agree.

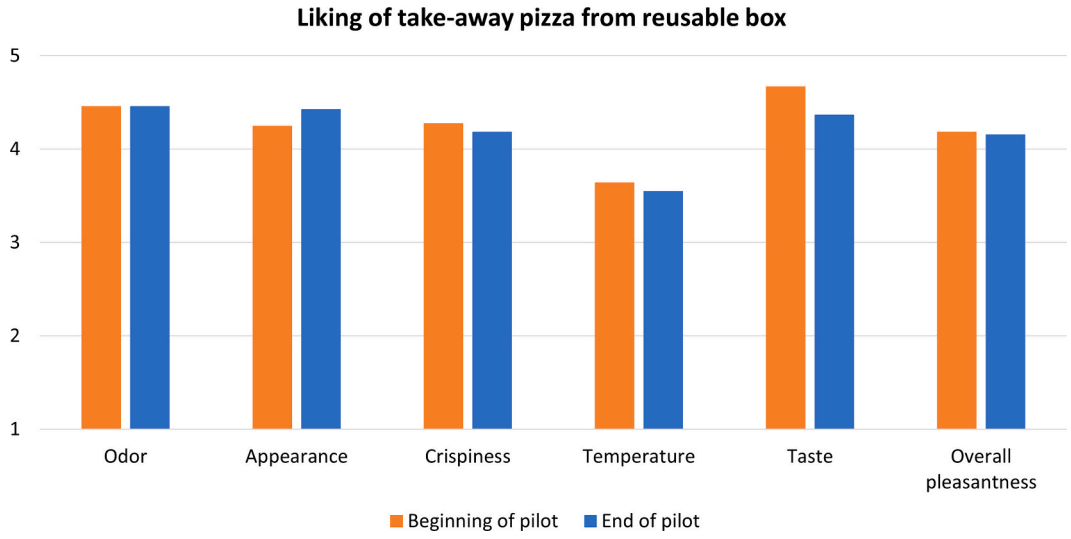

Fig. 6. Product evaluation in the beginning and at the end of the pilot. Bars represent means. Significant differences in main effects are denoted with different superscript letters. Scale from 1 = Extremely unpleasant, 5 = Extremely pleasant.

branded, well then you wouldn't be ashamed to put it on display […] it should be branded so it would be clear where one can get those and who uses them."

Interviewee #5

Environmental sustainability was connected to the *emotional value* that some consumers attribute to the packaging as some of them referred to positive feelings in connection with the contribution of the packaging to waste reduction. However, emotional value did not emerge often in the interviews.

Environmental value of the reusable takeaway pizza packaging was appreciated but also attracted scepticism. In comparison to the traditional packaging, some participants described the reusable takeaway pizza packaging as a "more sustainable option" while others expressed some scepticism over its environmental value. The color of the reusable takeaway pizza packaging (dark green) was associated with environmental friendliness and in some cases the contribution of the packaging to waste reduction was weighted against convenience.

"That of course, that there wasn't waste. And it was nice, that I didn't need to go to take out the trash right after eating. Of course, I did have to make a small effort of washing the packaging, but it is small thing compared to making less of unnecessary garbage."

Interviewee #7

Participants expressed some considerations on *price and cost* (financial and psychological) aspects. A deposit scheme was seen by consumers as a natural way to enable the use of the reusable pizza packaging. When suggesting a suitable deposit fee, consumers referred to the packaging size, the price of one pizza, the total amount of purchase and the amount of financial support by employee benefit schemes (e.g., lunch coupons). Suggestions for deposit fees varied between 1 and 10 €. Deposit fees between 1 and 4 € would encourage the (further) trial of the packaging and suit the purchase of several pizzas. Fees between 5 and 10 € would encourage some participants to take good care of the packaging and felt to them as a good amount to redeem (when returning the packaging). Memory, time, and cost appear to be particular challenges for consumers when planning to return the packaging to the pizza restaurants. For instance, remembering to return empty packaging was one of the identified burdens. However, the display of the packaging at visible spots within home helped some participants to remember to use and return it. In some cases, storage at home seemed to influence some consumers' decisions to return it. If storage of the packaging was not

seen as a particular challenge, then the empty packaging could remain at home for long periods of time, from few weeks up to entire pilot period. As one interviewee put it:

> "No, maybe since it was so easy to find [a space for storage], therefore I didn't return it. Otherwise, I could have returned it in between, but no, I didn't."
>
> Interviewee #1

Furthermore, some consumers were reluctant to return of the packaging as they perceived its return as an "extra trip" to the pizza restaurants resulting additional costs for them (e.g., gasoline price).

Convenience, environmental sustainability, storage, eating occasion, availability and amount of deposit seem to influence consumers' *intentions to use and recommend* the reusable packaging for take-away pizzas. For instance, the packaging would be used in the future because it was easy to carry, kept the pizza warmer and its toppings intact and in order to reduce waste and carbon footprint caused by take-away pizza consumption. Doubts in recommending the packaging concerned its storage and restrictions related to cutting the pizza in it. Furthermore, traditional packaging seems to be preferred over the reusable takeaway pizza packaging in occasions that take away pizzas are eaten outdoors (e.g., picnics, festivals, parks, cars), when travelling and when buying several pizzas (e.g., at parties). According to consumers, for such occasions at least one of the following challenges occurs for reusable takeaway pizza packaging: cutting the pizzas would be difficult and the packaging would need to be extensively carried after the use.

Finally, the pick-up of pizzas in reusable pizza packaging and/or the return of empty packaging in other pizza restaurants (than just those belonging to the restaurant chain where the pilot was carried) seem to moderate consumers' willingness to use the reusable pizza packaging. Increased willingness was justified with easier return options but also offering "freedom of choice" regarding pizza purchases whereas unchanged willingness was justified with loyalty to the restaurant chain and decreased willingness was related to worries regarding hygiene standards in other restaurants.

When considering *product evaluation,* the experience of take-away pizza from the reusable packaging was often compared by participants to prior experiences with traditional (i.e., cardboard) pizza packaging. In this context, the durability, odour, and temperature conductivity of the reusable takeaway pizza packaging influenced certain aspects of consumers' experiences. For instance, some interviewees made positive comments about the appearance of the pizza, noting that the topping of pizzas acquired in reusable packaging was intact as compared to prior negative experiences with traditional pizza packaging where a pizza's toppings could be found stuck in the lid. As one interviewee put it:

> *"With this* [e.g., reusable pizza packaging]*, the pizza looked much better. Since it fits there nicely and doesn't move. And well, almost like it was put directly to a plate at some restaurant."*
>
> Interviewee #4

Also, for some consumers the overall eating experience was better since the packaging itself did neither loose its shape nor got humid (due to pizza's gradual loss of temperature when being within a packaging). Regarding the odour of the packaging itself, some consumers recalled that the cardboard material's odour used had a negative impact to the taste of the pizza whereas this was not the case for pizzas from reusable packaging. The temperature conductivity of the packaging had a positive or negative influence to consumers' perceptions of taste and odour. For instance, colder pizzas felt for some participants less tasty and odourless (in negative way).

4.1.4. Perceived Value and Intentions towards Reusable Pizza Packaging in Online Survey

The Kruskal-Wallis test results related to Finnish, UK, and German consumers' perceived value of reusable take-away pizza packaging are reported in Fig. 7. The scores reached above or close to 3 in all measured dimensions. The analysis revealed some differences between the countries. In functional value, German consumers showed higher evaluations, $X^2(2) = 39.26$, $p < .001$. All countries differed from each other in perceived environmental value, $X^2(2) = 50.25$, $p < .001$. Again, German consumers evaluated the reusable pizza packaging environmental value highest followed by UK and then Finnish consumers. UK and German consumers did not differ in their perceived social value evaluations while Finnish consumers made the difference, $X^2(2) = 45.08$, $p < .001$. Finally, consumers from all countries differed from each other in perceived emotional value, $X^2(2) = 107.80$, $p < .001$. German consumers gave the highest evaluations while Finnish consumers the lowest. UK participants were in the middle.

With regards to intentions towards reusable take-away pizza packaging (Fig. 8), German consumers showed highest scores, $X^2(2) = 58.66$, $p < .001$. The average score for Finnish and UK participants is close to each other yet differ significantly. Overall, the intentions are three or above in a scale from 1 to 5 indicating average intentions in all countries.

4.2. Business Desirability and Feasibility: Employee and Managerial Experiences of the Reusable Pizza Packaging

4.2.1. Business Desirability: Potential Positive Impacts to Brand Value and Image

In the case of reusable pizza packaging, desirability of business model among restaurants owners is highly relevant for the uptake and scale-up of new circular reuse models. Several interviewed franchisees identified that the performance and perceived environmental benefits due to lower packaging waste generation were the main arguments for adopting reusable takeaway pizza packaging.

High managerial motivation in participation to the pilot was linked with customer-orientation and potential for cost savings in comparison with single-use fibre-based packaging. Assumed environmental benefits, such as reduced disposable packaging waste generation due to packaging reuse, may improve reuse model's desirability among restaurant franchisees. Some of the interviewees emphasized that achieving environmental benefits can contribute to corporate responsibility, help differentiate themselves from competitors and improve brand image. In addition, the packaging solution was seen to "*Fit well with company's values*", as stated by a franchisee. Adopting reusable takeaway pizza packaging was also seen to improve employer image, as piloting reusable pizza packaging was also seen to fit to young employees' and also customers' values, as shown here:

> "Some employees were proud to take this kind of thing [reusable takeaway pizza packaging] forward."
>
> Interviewee #13

4.2.2. Business Feasibility: Operational Performance and Usability

We studied business feasibility, i.e., how reusable takeaway pizza packaging uptake can be organised to deliver value, through impacts to operational performance and usability in case takeaway restaurants. Both managerial interviews and the online staff surveys indicate that the reusable pizza container served well for the purpose during the pilot. For example, 72 % of survey respondents perceived reusable takeaway pizza packaging to suit well for selling pizza. Relatively easy handling and the use of the reuse system, as well as convenient cleaning, were seen to contribute positively to the packaging performance.

The main drawbacks, as seen by the staff members, revolved around the technical problems related to scanning of the containers during the checkout and check-in at the restaurants. From the managerial perspective, the main challenges also focused on technical issues during the pilot. The use of reusable container was seen to slightly slow down the operations due to separate cutting of pizzas, insufficient drying

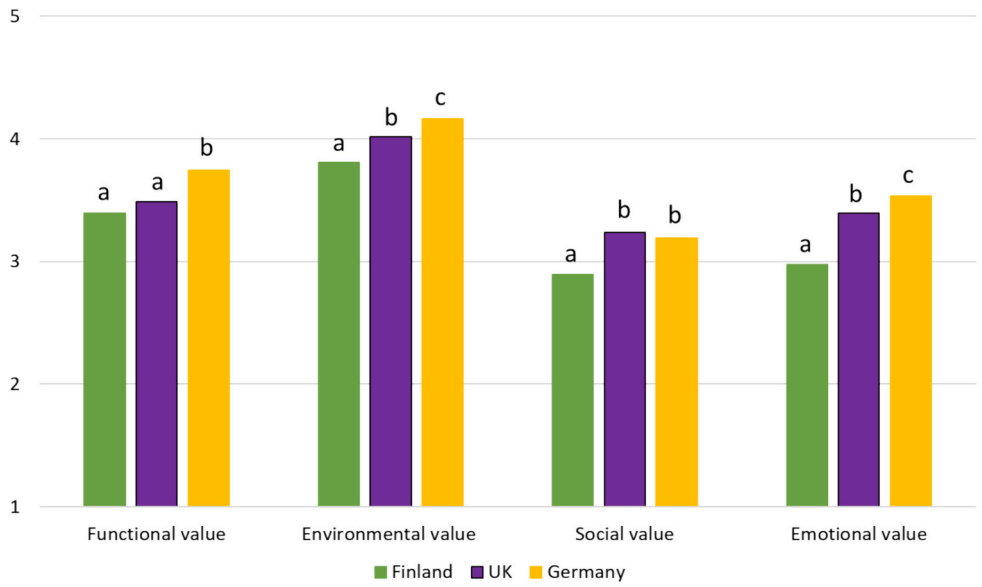

Fig. 7. Mean perceived value of reusable take-away pizza packaging in Finland, UK, and Germany. Significant differences between countries are denoted with different superscript letters. Scale from 1 = Totally disagree, 5 = Totally agree.

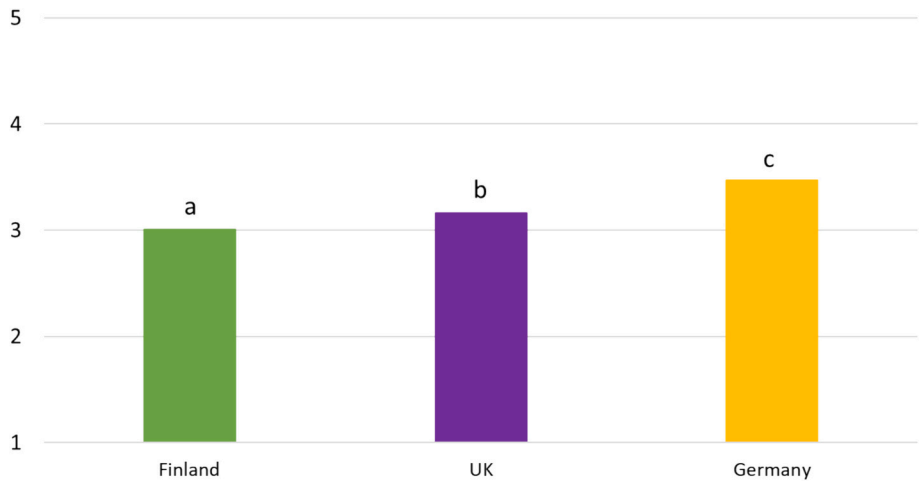

Fig. 8. Mean intentions to test, buy and recommend reusable take-away pizza packaging among Finnish, UK, and German consumers. Significant differences between countries are denoted with different superscript letters. Scale from 1 = Totally disagree, 5 = Totally agree.

capacity of the dishwashing machine and problems with the scanning of QR codes.

From a usability perspective, some of the respondents found it difficult that the pizza could not be cut in the packaging due to scratching, which slowed down the operations at the restaurant. Some of the staff members also shared concerns about discoloration of reusable takeaway pizza packaging and that they are easily scratched in use, which may ruin the packaging prematurely.

As a deposit system for returnable pizza packaging is still in piloting stage, consumer education and marketing of this new type of packaging requires additional efforts by restaurant staff. During the pilot, some of the employees found it challenging to find time to promote the deposit-based reusable takeaway pizza packaging to the customers. In general, explaining of the benefits of the reusable takeaway pizza packaging to the customers was also experienced as difficult.

To summarise, depending on the restaurant, its sales volumes, and the share of takeaway food sales, increasing the use of reusable take-away pizza packaging may require changes in, for example, washing capacity and storage space as well as online sales system to allow consumers to conveniently select reusable packaging for their pizzas.

4.3. *Environmental Sustainability of Reusable Pizza Packaging*

Findings from the in-depth interviews with the sustainability experts of the companies involved in the reusable pizza packaging case study enriched with the information gathered from the company websites and sustainability reports are presented below. The findings are reported one lifecycle phase (packaging design, production and manufacturing, distribution, use, collection, reuse, and end-of-life) at a time. Finally, the most influential factors, which the interviewees highlighted from reusable pizza packaging environmental sustainability perspective are described.

4.3.1. *Packaging Design*

The interviews indicated that the environmental sustainability is important, but not the first criteria for the packaging design for the pilot companies. When designing the packaging, the interviewees said that the safety and quality of the products, in this case pizza, are the most

important things to consider and prioritize. According to the interviews, the environmental sustainability issues are seen to be important factor once the safety and quality are covered.

As one interviewee put it:

> "The quality of the product is the first demand from the consumers and therefore it is also the first demand for us. The quality and safety must come first and once they are ok, we can start to think about the environmental aspects in the design phase."
>
> Interviewee #18

4.3.2. Production and Manufacturing

The interviewees considered production of the plastic raw material and manufacturing of the reusable takeaway pizza packaging as important from environmental sustainability perspective. According to them, these phases constitute a large share of the reusable pizza packaging environmental effects. As one of the interviewees said:

> "The weight of the material has a profound effect on the environmental burden of the packaging. 30-40 % of the total environmental effects of the reusable packaging are caused by the raw material production."
>
> Interviewee #19

The environmentally sustainable raw material choice seemed to have a role in interviewees' minds. However, the interplay between the raw material options and packaging functionality caused some concerns and open questions:

> "It would be very good if we could develop the packaging to be more CO_2 neutral by developing such raw materials that have good mechanical features. Now e.g., wood-based raw materials have been tested but they are not mechanically durable enough. They don't for instance bear heating especially if put in the microwave oven."
>
> Interviewee #19

The quotes from the interviewee #19 stress that the raw material production is perceived to be one of the lifecycle phases where significant amount of the total environmental effects of the reusable takeaway pizza packages are caused. This indicates that raw material selection is among the key issues to be taken into consideration if the environmental effects of raw material production and packaging manufacturing are to be minimized. This is also linked to the previous lifecycle phase, packaging design, in which the raw material selection is made.

4.3.3. Distribution and Logistics

According to the interviews, the main factors influencing the environmental impacts of reusable pizza packaging logistics and distribution are the weight and size of the pizza packaging, distances between the restaurants, washing facilities, and collection points. The next quote illustrates the importance of logistics in general and washing in particular:

> "30-50 % of the environmental impacts are caused by washing, 30-40 % are caused by raw material production and the rest is caused by logistics. The biggest difference, around 20 %, of the effects caused by logistics is dependent on the washing…if it is done in the restaurants or in a separate washing facility."
>
> Interviewee #19

The importance of logistics is also visible in the webpage of one of the pilot companies. The company that has piloted the reusable pizza packaging in their restaurants and offered them to their customers (B-to-C) stated in their web pages that they are making sure that the logistics are handled with as low environmental effects as possible. This is ensured by their logistics partners who follow the laws and regulations, respect human rights, and take care of the environment.

4.3.4. Use and Reuse

The interviewed sustainability expert of the company that has piloted the reusable pizza packaging in their restaurants and offered them to their customers (B-to-C) stated that consumers' perceptions concerning the packaging ease of use and functionality are important to harness the environmental sustainability benefits. This illustrates that the company realizes they cannot implement the reuse system without engaging the consumers.

> "The main thing to consider from the environmental sustainability viewpoint is that what if it is not easy and functional for the consumers. Then all efforts have gone to waste."
>
> Interviewee #18

Another major issue emerged. This relates to how many circulations the packaging can handle in use before its quality deteriorates, which directly touches the environmental sustainability potential. As one of the interviewees put it:

> "The biggest question mark is how many rounds the packaging can really circulate. To define the boundary value when the packaging is still usable considering the surface damages or color damages is not always easy. Some spices can for instance cause coloring issues but they are not a hygiene issue, just an aesthetic issue."
>
> Interviewee #19

4.3.5. Collection

According to the interviews, the collection phase was seen as an important lifecycle phase of the reusable takeaway pizza packaging. This is because the entire reuse model cannot produce the environmental benefits, if the packaging return is not handled properly by consumers and collection by companies. Thus, sufficient collection of the packaging is an important condition for reuse to take place. As such, the collection was not seen as a factor causing a lot of environmental effects.

4.3.6. Washing and Reconditioning

The interviewees perceived the washing and reconditioning of the reusable pizza packaging among the main factors conveying the environmental effects. As one interviewee said it:

> "30-50 % of the environmental impacts are caused by washing. The washing times, washing temperatures and chemicals used are the things that cause environmental impacts. Especially the high washing temperature is the main factor… We cannot use too low temperatures due to hygienic issues."
>
> Interviewee #19

During the interviews, a lot of discussion was made about the washing taking place either in the restaurants (decentralized washing) or at separate washing and reconditioning facilities (centralized washing). The complexity is highlighted well from a situation of one interviewee:

> "In the decentralized washing, the environmental effects are divided between reusable packaging and plates, cutlery, etc. things that are being washed at the restaurants daily anyway. In the centralized washing, there are extra logistics needed and lost heat from the washing. How is the lost heat used? Is it used wisely for instance warming of the facility or not, makes a difference from the viewpoint of environmental sustainability."
>
> Interviewee #19

4.3.7. End-of-Life Management

In this specific case study of reusable takeaway pizza packaging, the applied end-of-life management strategy is recycling. According to the webpages of the startup developing the reusable pizza packaging, it is

said to be "*100 % recyclable*". One of the interviewees said that:

> "Once it [the reusable takeaway pizza packaging] has reached the end of its life cycle we return it to the manufacturer to be recycled as raw material. Recycling 100% of the material saves a significant amount of new raw material, which significantly reduces the environmental impacts."
>
> Interviewee #19

Besides having an influence on the production and manufacturing phase, the chosen end-of-life management strategy has an influence also on the design phase since the packages need to be designed for recycling.

4.3.8. *Interviewees' Stand on the Key Lifecycle Phases and the most Influential Factors Affecting the Environmental Sustainability*

According to the interviews, the three lifecycle phases affecting the environmental sustainability most were reusable pizza packaging washing, raw material production, and transportation of the packaging between the restaurant, collection point and possible washing and reconditioning location (Table 4). According to the interviewees, washing can cause up to 50 % of the environmental effects. Heating of the water (due to high threshold for improper food safety and hygiene) was considered the most influential factor when evaluating the environmental effects of washing. Further, the washing times and used detergents and washing chemicals cause environmental effects but were not perceived as dominant factors as heating of the water.

The raw material of the reusable pizza packaging is currently fossil based virgin plastic with high production related environmental burden. As stated by the companies' sustainability experts, this causes 30–40 % of the total environmental effects. In the raw material production phase the material choice and the weight of the packaging were perceived the main factors that have significant influences on the environmental sustainability. The interviewees were hoping to lower the environmental effects of the reusable takeaway pizza packaging by changing the raw material from fossil-based plastic to some other raw material, but the challenge is mechanical durability.

Logistics was the third most influential life cycle phase from environmental sustainability perspective. The interviewees considered that choice between location of the washing facility (centralized vs. decentralized washing) was important. In addition, the distances between the restaurants, washing facilities and collection points were emphasized along with the weight and size of the pizza packaging.

4.4. *Technical Feasibility: Packaging Condition Analysis of Reusable Pizza Packaging*

The overall appearance and condition of 12 pizza packaging samples (Fig. 9) were visually inspected with naked eyes before the microscopic inspection.

The location, dimension and orientation of observed scratches and wear marks were recorded. The 12 samples visual condition analysis is summarised in Table 5.

Following the naked eyes observation, microscopic inspection was performed. The microscopic images were taken for in-depth conditional analysis of the 12 pizza packaging samples from 3 spots per packaging. The microscopic images are presented in the Supplementary materials S5. The relative estimation of scratching share over the sample spot area are calculated and result is presented in Table 6. Withdrawing from the relative scratching calculation, the typical result is under 10 % with 2 exceptions of 3-cycle most worn spot 1 (15.8 %) and 4-cycle least worn spot 1 (21.14 %). The outer surface spot's scratching share is often lower than inner surface.

Table 7 presents the observations of key 6 categories of the packaging condition.

To conclude, with low recirculation of under 4 cycles, scratching and wearing condition is more dependent on the use and handling rather than the amount of use cycles. The scratches are located with the increasing frequency to the centre area of the circle packaging with the orientation to the middle point. Scratches on the outer surface are typically less in quantity and severity than inner surface but still visible with naked eyes. The shape and dimensions vary with typical shape being straight, curvy and dot and irregular shapes. Naked eye observation is better to demonstrate a comprehensive view on the scratch progression, location and orientation, and shape and dimension. Meanwhile microscopic inspection increases the visibility to assess the minor scratches, cumulative effects of overlaps and crosscuts, and the plastic surface modification including chip formation and scratch indentation. However, pileups from scratching cannot be identified with optical microscopic inspection.

Table 4
Key lifecycle phases and factors effecting the environmental sustainability the most in the case of reusable takeaway pizza packaging based on the perceptions of the interviewees (sustainability experts of the companies involved in the reusable takeaway pizza packaging pilot case).

Lifecycle phases where most of the environmental impacts are created	Factors effecting the environmental sustainability the most in each of the lifecycle phases
Washing of the reusable takeaway pizza packages	• Heating of the water • Use of chemicals • Washing times
Raw material production and product manufacturing of the reusable takeaway pizza package	• Used raw material • Weight of the pizza packaging
Logistics	• Distances between the restaurants, washing facilities and collection points • Weight and size of the pizza packaging

4.5. *Conceptual Framework Based on Literature and Pilot*

As an outcome of the literature review, workshops leading to the design of the pilot and the pilot itself resulted in providing practical insights on the various factors affecting the desirability, feasibility, and sustainability of a reusable takeaway pizza packaging business model. The framework offers an illustration of individual factors influencing the feasibility, desirability, viability, and sustainability for developing reusable takeaway pizza packaging business model. The factors have been derived throughout the different steps of the methodology. Though not directly tackled upon in the current stage of the business model innovation process, an additional set of business viability factors were also identified throughout the interviews with the informants and completed by the existing literature. Fig. 10 below offers a conceptual framework summarizing these factors.

Supplementary Information S6 provides a detailed overview of where from the pilot and literature the presented factors were derived. The conceptual framework has been drafted based on and from the perspective of the single case study for takeaway food (pizza) packaging. The framework may offer, however, insights into designing and developing other types of reusable food packaging and furthermore, reusable packaging for FMCG. Whilst the results offer practical insights that may scale to other solutions, the replicability and scalability of the conceptual framework to other cases has not been the focus of this study.

5. Discussion

In the following sections, we first discuss the conceptual framework, then delve into the theoretical and practical contributions of our research, limitations of the study and provide directions for future research.

5.1. *Conceptual Framework and the Four Dimensions*

The framework provides an initial check list of individual factors affecting the feasibility, desirability, viability, and sustainability of a

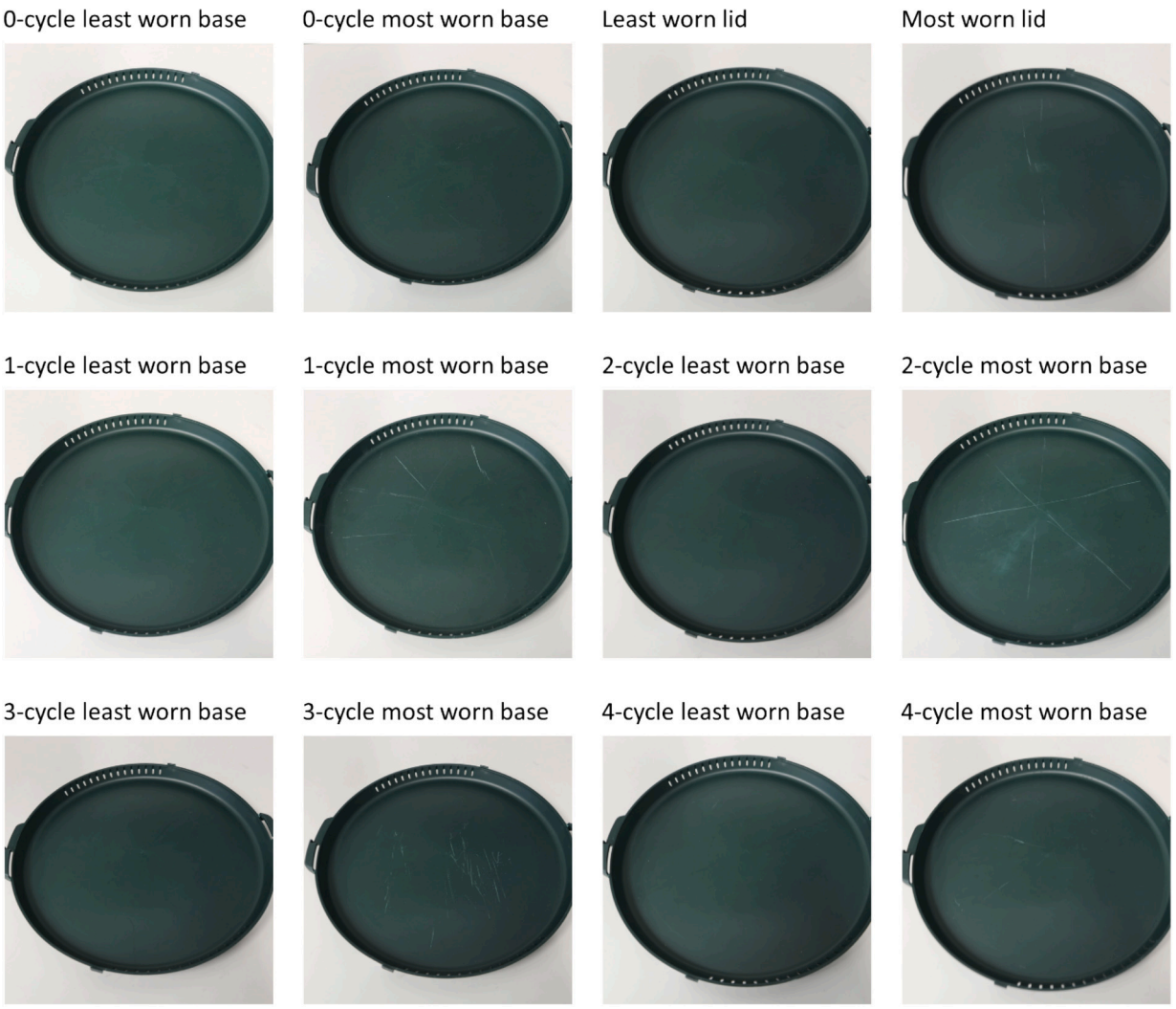

Fig. 9. Reusable takeaway pizza packaging samples.

reusable takeaway pizza packaging business model in development phase. It also allows to make visible some interconnections between individual factors from different dimensions, thus highlighting that developing strategies to make the business model feasible may for instance impact the viability or sustainability of the system. Examples of such connection may for instance be the optimization of the number of cycles, that should be tackled from a feasibility perspective (designing a packaging that sustains a large amount of cycles) yet realising it simultaneously impacts the sustainability dimension of the business model (more cycles diminishes the overall impact of the system) and its viability (more cycles diminishes the need to replace packaging in circulation with new one thus reducing the costs).

Testing and validating the feasibility, desirability, and viability of circular business models can indeed facilitate the implementation and scaling of reusable business models (Bocken and Konietzko, 2022), while assessing their sustainability potential from the outset can support their environmental value proposition (Manninen et al., 2018).

Regarding *feasibility* and *desirability* dimensions, the first aim is to understand to what extent the new circular value proposition can be concretely implemented. An initial assumption is to focus on the key characteristics of the packaging itself and validate if the *packaging feasibility* and its functionality, durability and safety requirements enable the reuse expectations of the business model. In that context, scratching was evaluated to explore to what extent the packaging itself can sustain several cycles. According to Accorsi et al. (2020), how many cycles a packaging can circulate can be seen as a key parameter, this finding is also underlined in the study. Scratched packaging might not look visually appealing or feel safe to use, and it might be lead to early discarding.

Given the systemic nature of the reusable business model, it is also necessary to assess the *system feasibility* of the new business model. New activities related to collection, cleaning, and maintenance of the reusable packaging, as well as its digital tracking need to be put in place to ensure that the new solution can be effectively implemented. Enquiries with key staff directly involved in restaurants highlighted specific aspects to consider such as additional space for storage and drying reusable takeaway pizza packaging, concrete instructions to ensure tracking process of the packaging as well as additional expenses in communication and marketing. Eventually, the behaviour of the end user when handling the reusable takeaway pizza packaging can strongly influence its condition and associated lifespan thus influencing the feasibility and viability of the business model.

Iacovidou et al. (2021) emphasize that reuse is accompanied with technical and operational challenges; however, the success of B2C reusable packaging circular business models is similarly dependent on the decisions and choices of consumers. Alongside product and system feasibility, assessing to what extent the solution is *desirable* from a consumer perspective is a crucial dimension to explore (Bocken and Konietzko, 2022). In the context of reusable takeaway pizza packaging, consumers' desirability is shaped by rational considerations (e.g.,

Table 5
Naked eyes' inspection summary of pizza packaging visual condition.

Type	Cycle	Sample	Naked eyes observation
Base	0	Least worn	Pristine condition, some light white trace that is not so visible and can only be seen when changing the view/light angles.
		Most worn	Several dot scratches forming a dot cluster orientating to the middle point and some short curvy scratches forming a clear intermittent white trace near the edge.
	1	Least worn	Good condition, few minor and not so visible scratches.
		Most worn	4 clear straight scratches (5–8 cm) placing from the edges towards the middle point, 2 other lighter long scratches (10–12 cm) and some other short scratches overlapping and cutting each other. There are water marks on the outer surface.
	2	Least worn	Good condition, few minor and not so visible scratches.
		Most worn	3 clear long straight (22–25 cm) scratches cutting through each other at the middle point to the edges of the packaging, some other minor scratches.
	3	Least worn	Few short (2–3 cm) light scratches near the edge with no specific orientation.
		Most worn	Many intermittent scratches (long, short, dot with varied length) forming vertical cutting traces through the middle point. Scratches are overlapped with each other, like they were cut to the same area several times.
	4	Least worn	Minor scratches forming a light white trace near the edge.
		Most worn	Several clear short scratches (2–4 cm) with different starting points and orientating to the middle point.
Lid	N/A	Least worn	Some small light scratches that are not so visible, the outer surface is more worn.
		Most worn	Clear intermittent scratches (3–5 cm) forming a long vertical cut through the middle point, looks like it has been used as a base and the scratches were caused by cutting pizza.

Table 6
Relative scratching share of the reusable pizza packaging samples.

	Cycle	Sample	Spot 1 (In)	Spot 2 (In)	Spot 3 (Out)
Base	0	Least worn	2.49 %	4.13 %	0.11 %
	0	Most worn	0.79 %	6.84 %	3.09 %
	1	Least worn	0.58 %	0.08 %	1.92 %
	1	Most worn	8.00 %	8.43 %	7.55 %
	2	Least worn	0.01 %	1.78 %	6.90 %
	2	Most worn	8.82 %	3.87 %	2.39 %
	3	Least worn	0.85 %	1.03 %	2.52 %
	3	Most worn	15.80 %	3.35 %	0.62 %
	4	Least worn	21.14 %	0.06 %	2.41 %
	4	Most worn	9.38 %	3.09 %	3.60 %
Lid	N/A	Least worn	2.82 %	0.91 %	3.16 %
	N/A	Most worn	3.81 %	6.30 %	0.62 %

functionality, environmental sustainability, cost, sacrifice, product experience), an affect state or component (e.g., emotional value) and social acceptability (e.g., social value). Some of these elements may have a positive or a negative influence on desirability. For instance, functional aspects such as the external temperature of the box was perceived as "pleasant" but also as "burning hot".

As circular business models for reusable takeaway pizza packaging are nested in complex interactions between different stakeholders (brand owner, service operator, franchisees, end users), the desirability of the new business model cannot only be assessed from a consumer/end user perspective. As presented by Dada et al. (2023), the business's success relies on both consumer participation and internal stakeholders' (e.g., staff, franchisees) embrace of the new model and engagement with consumers. Taking a system approach to desirability will require to validate to what extent the solution is desirable among the key stakeholders involved in implementing the business model. In this case, managers from franchisees and most importantly restaurant staff marketing the reusable takeaway pizza packaging option also need to be convinced of the benefits associated with the alternative, whether it is about improving brand image or actually aligning with expectation from customers related to green behaviour. Restaurant staff not finding the new solution desirable may be reluctant to promote the reusable takeaway pizza packaging option to end-users, thus putting its successful distribution at risk. Making the solution desirable for them should therefore not be underestimated.

For *business viability* dimension at product level, the cost of the packaging itself, the operational costs to run the system and the volume of sales have to be balanced with the systems dimensions affecting the financial viability of the new business model. Additional infrastructure and operational costs must be considered to enable circulation, and key dimensions to consider when validating the viability of the business model include return rate, cycle time and the expected number of cycles to be achieved in order to reach breakeven point. As Coelho et al. (2020) state, the return rates vary between different systems and are positively affected by deposit fee systems.

Addressing the *sustainability* dimension of the business model can also be addressed from a narrow perspective, focusing on the packaging itself, validating to what extent the design, manufacturing processes, distribution and use phases are integrating environmental considerations. A systems perspective however will complement the packaging assessment to address the additional phases required by the reuse of the packaging, namely collection (and its logistics choices), reuse (washing, storage, redistribution) as well as the end-of-life stage.

5.2. Theoretical Implications and Future Research

The findings of this study contribute to several priority areas in current circular economy research, reusable food packaging and reuse business model development. The contributions to circular business model literature by unraveling and linking factors that may facilitate or hinder a systematic transition towards circular business model. Circular business models require companies to adopt a systemic perspective for managerial practices implementation in all the dimensions of value (Centobelli et al., 2020), yet investigation on how a systemic perspective can help designing circular business models has been scarce (Ünal et al., 2019). To fill this gap, the study has taken a multidisciplinary approach

Table 7
Microscopic analysis remarks of pizza packaging samples.

1. Scratch progression	2. Location and orientation	3. Shape and dimension	4. Cumulation	5. Visibility	6. Surface modification
Scratching and wearing condition do not correspond to the usage cycles	Location and orientation are better to view as a whole	Typical straight, curvy and dot scratches	Scratch cumulative effect deepening surface deformation	Minor and light scratches detected	Chip formation from the scratches detected
	Orientating to middle point	Irregular scratching shapes identified better	Overlapping and cross-cutting points identified better	Better surface deformation visibility	Scratch indentation and subsurface modification detected
Scratching share calculated is typically under 10 %	Outer surface scratches detected which are irregular in orientation	Dark trace of wear marks detected		Better view on water mark effect	Pile-ups cannot be detected with optical microscope

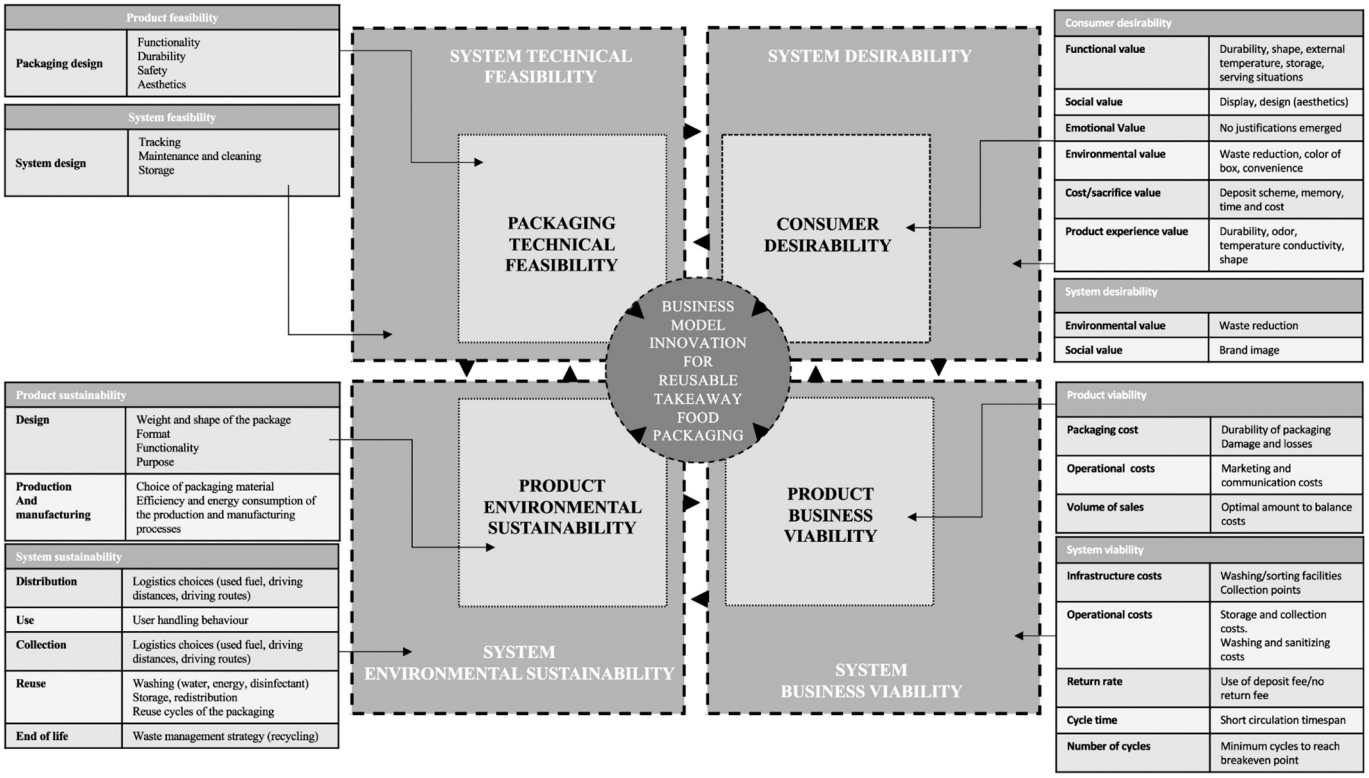

Fig. 10. Factors affecting Business model innovation for reusable takeaway food packaging. The framing conditions have been adapted based on Bland and Osterwalder, 2019; Bocken et al., 2022; the factors have been derived based on the carried out research and the pilot as well as enriching it with relevant literature (Accorsi et al., 2014, 2020; Camps-Posino et al., 2021; Coelho et al., 2020; Cottafava et al., 2021; Germann et al., 2022; Greenwood et al., 2021; Gross et al., 2018; Hakola et al., 2023; Iacovidou et al., 2021; Lofthouse et al., 2017; Miao et al., 2023; Willemijn et al., 2023; Ponce et al., 2009; Potting and van der Harst, 2015; Salo and Hylkilä, 2023; Schuermann and Woo, 2022; Tenhunen-Lunkka et al., 2023b; Yadav et al., 2024).

to identify and characterise technical, financial, environmental, and social factors that may need to be considered when designing a circular business model. The conceptual framework introduced in the result section highlights the need to iteratively navigate between the packaging/service that is redesigned to be reusable and its associated system of infrastructure, actors and activities. It also calls for an iterative dialogue between the four dimensions scrutinized.

Second, large stream of circular business model research has focused on developing business model taxonomies, typologies and patterns with the goal to frame, classify and explicate value creation mechanisms supporting the generation of new circular business models (Lüdeke-Freund et al., 2019; Pieroni et al., 2021; Rosa et al., 2019). This research, while zooming into a specific sub-stream of circular business models – reusable food packaging business model - adds an additional layer of granularity and offers an extensive set of factors that should be addressed in the business model innovation phase. This level of granularity provides a rich starting point to explore, and systematically frame the wide range of variables that can possibly be adjusted when developing circular business models.

Third, we highlight inherent tensions in dealing with the four dimensions, which builds on current literature in the field. As highlighted by De Angelis (2021), their study summarises that research on circular business models deriving from circular economy implementation is rather limited; moreover, studies of tensions in circular business model implementations are limited. To reduce the design-implementation gap in circular business models (Baldassarre et al., 2020), it is essential to balance desirability, viability, feasibility, and sustainability. This study builds on the theoretical knowledge of building a circular business model on multiple lenses. A reusable packaging system that is highly desirable, economically viable, technically feasible and environmentally sustainable is more likely to succeed. However, as illustrated in the case study, achieving this balance can be challenging, as there are specific trade-offs between these four dimensions. For instance, the durability of the packaging, defined as a design requirement to convince consumers to use the service longer, can negatively affect the production cost of the packaging and stress the viability of the system. Similarly, ensuring high safety and hygiene as a feasibility requirement may impact the environmental sustainability of the packaging through intense washing, use of chemicals as well as discarding the packaging from the reuse cycle before at the end of its technical life. However, some connections can be positive. Cost efficient logistics will improve the viability of the system while reducing environmental impacts of transportation. A durable packaging will increase the probability of a high circularity rate and hence offers improved sustainability. Designing circular business models thus is inherently about navigating the inherent tensions between what is feasible, desirable, viable, and sustainable. To achieve a balance between these four dimensions, it is essential to iterate and refine the business model design and development process. This requires ending experimenting to reduce uncertainties, receive feedback from the ecosystem actors (consumers, partners, suppliers) on what is desirable and feasible, as well as an ongoing evaluation of costs, revenue structure and environmental impacts to achieve long term financial viability and sustainability.

5.3. *Practical Implications*

From a practical perspective, this study offers several important insights for companies interested in designing reusable packaging circular business models. However, as the conceptual framework has been drafted based on and from the perspective of the single case study for takeaway food (pizza) packaging, the generalisability of the results to other reusable packaging systems has not been studied as part of the

research carried out. The framework may, however, offer insights into designing and developing other types of reusable food packaging and furthermore, reusable packaging for FMCG. First, the study answers the call to analyse not only the outcome of circular economy implementation in a company's business model but also the process according to which the results are achieved, (i.e., the business model dimensions involved) and the interdependencies between these dimensions. By illuminating the challenges and tensions resulting from the various dimensions analysed in practice, this study develops insights on how actors can use experiments to fill the gap between business model design and implementation (Baldassarre et al., 2020). Small scale pilots, user surveys, stakeholders' interviews, laboratory tests are all elements of an experimentation portfolio that needs to be conducted and analysed using a transdisciplinary lens towards a unified objective: reducing uncertainties and building a robust circular value proposition that can meet its promises.

The study offers new insights to marketers and more specifically to customer value proposition design. The shift from a linear to a circular economy calls for a different approach to designing value propositions, expanding beyond superior products features and functional benefits created through new value-in exchange opportunities, towards enhanced customer experiences combined with superior environmental and economic value created through value-in-use opportunities (Ranta et al., 2020). This shift resonates with contemporary marketing literature emphasizing cocreation with multiple stakeholders in broader societal ecosystems (Chandler and Lusch, 2015). In the case study, we illustrate this shift, emphasizing the need to involve multiple stakeholders in the co-design of new circular value propositions (end users, service operators, franchisees, restaurants staff) based on a solid foundation of multiple co-benefits embracing functional, social, emotional, cost/sacrifice, product experience value alongside environmental value. When developing circular value propositions, managers should highlight how the different values associated with the new solution stand out as opposed to the linear approach, as consumers tend to unconsciously compare the new alternative with the former. A sole focus on the environmental benefit is not sufficient and additional benefits (including improved functional value) should be highlighted.

5.4. Limitations

The study has several limitations relating to the single-case study approach pilot case, which is in its designing and development phase, not evaluation phase as it is not a ready commercial business model. Further limitations relate to the framing from the research project and following data requirements, the selection of participants and lack of broader systemic analysis of the interconnectedness, the sustainability analysis, and scalability of the results beyond reusable takeaway pizza packaging. The findings from this study are derived from a single case study focusing on one specific type of reusable packaging business model – e.g., sequentially reused products systems (Muranko et al., 2021). If insights provide some indication and evidence on the factors to consider when developing a reusable packaging circular business model, it is yet to be generalized in other reusable packaging business models and extended to circular business models in general. The framework developed in this specific context of reusable takeaway pizza packaging could, however, be tested and complemented in other circular business models development case studies, particularly those focusing on product-service systems.

Furthermore, as this case study was developed within the context of a specific research project, data collection did not extend beyond the end of the project, thus limiting knowledge creation regarding some of the aspects of the presented dimensions and the final developments of the novel business model. For example, as there were ready solutions for the tracking, washing, and redistribution of the packages in the pilot, the focus of the technical experiments did not extend to these topics. They however are important parts of setting up different types of reusable packaging systems and should be studied further e.g., in business models where the set-up is different. Revisiting the development of this circular innovation over time could generate additional knowledge and insights. Moreover, costs-revenue mechanisms of the new business model were not investigated further as a specific revenue approach was previously defined by the service operator and agreed with the restaurant franchisor. The focus on staff and franchisees acceptance as a bottleneck to future profitability was deemed more important by the involved stakeholders. Yet, we recognize the importance in future research to study further revenue mechanisms alternatives and their impact on profitability.

The selection of the pilot participants (i.e., consumers) were already interested in the reusable packaging solution. It is possible that such interest may have influenced some of their responses, for instance, intentions were relatively high at the beginning of the pilot (above 4 in a scale from 1 to 5 where 1 is the lowest and 5 is the highest evaluation point). However, significant differences at the beginning and end of the pilot (e.g., intentions, taste) and findings from the interviews suggest that participants were able to be adopt a critical approach when evaluating the solution. Participant interviews, for instance, revealed challenges (e.g., serving of the pizzas), concerns (e.g., cost) and scepticism (e.g., environmental sustainability) related to the solution. Another limitation concerns the small number of involved pilot participants ($N = 33$). For instance, the number of participants' responses may not suffice to understand perceptions of a larger consumer group. Nevertheless, number of responses were enough to assess whether pilot participants' perceptions, intentions and product evaluations change over time (i.e., from the beginning to the end of the pilot), which was one of the aims related to the consumer desirability part of this study. Furthermore, findings from the broader survey administered in Finland, Germany, and UK ($N = 2400$) share some similarities with those from the pilot study. For instance, a similar pattern can be observed in consumers' evaluations in perceived value dimensions, with environmental sustainability being followed by functional, emotional, and social value.

The selection of the methodology used in the environmental sustainability of reusable takeaway pizza packaging is limited to a single pilot case that is in the design and development phase. The environmental sustainability of the reusable takeaway pizza packages was assessed based on the individual perceptions of two sustainability experts involved in the pilot case. The LCA calculations were not a feasible option to enforce due to the fact that there was no reliable data available. Therefore, the results regarding the factors affecting the environmental sustainability of reusable takeaway pizza packages are not to be generalized for other reusable packaging solutions. Finally, if the results highlight a set of interconnections between factors appearing the four dimensions of the framework, there has not been a thorough systematic analysis of the depth and directions of interconnections between these factors, thus providing limited knowledge on which factors to tackle in priority to generate positive feedback. This should be carefully considered when deriving generalized conclusions from the conceptual framework developed in the context of this single case study zooming in on the reusable takeaway pizza packaging.

6. Conclusions

We explored *consumer desirability* of reusable pizza packaging, uncovering key factors shaping their choices. Convenience, environmental sustainability, storage, eating occasion, availability and amount of deposit seem to influence consumers' intentions to use and recommend the reusable packaging for take-away pizzas. It was noticed that consumers often compare the reusable option to traditional packaging, noting challenges like increased dishwashing. Comparisons with traditional packaging influence experiences, with factors like durability and temperature conductivity impacting perceptions. Social value is tied to the packaging design, it was seen that a unique packaging could create interest and contributing to branding. Environmental sustainability is

linked to positive feelings for some consumer; however, scepticism occurs about the actual impacts. A deposit scheme was seen by consumers as a natural way to intensify return - for some consumers, fees between 5 and 10 € were considered reasonable and were seen to encourage to take good care of the packaging. Returning the packaging encounters challenges, including remembering to do so and logistics, with pickup locations influencing consumer willingness for return.

Research conducted examined *business desirability and feasibility* from the perspectives of employees and managers. The success of circular, reuse models depend on restaurant owners' interest in the business model. Key findings highlight that implementing reusable packaging may necessitate adjustments in washing capacity, storage space, and online sales systems, particularly for restaurants with varying sales volumes and takeaway percentages. The primary factors impacting the *environmental sustainability* of reusable pizza packaging are washing, raw material production, and transportation between the restaurant, collection point, and potential washing/reconditioning facility. *Technical feasibility* focused on investigating the scratching behaviour in relation to the amount of reuse cycles. It can be concluded that with low recirculation of under 4 cycles, scratching and wearing condition is more dependent on the use and handling rather than the amount of use cycles the packaging has endured. This highlights the importance of efficient education and communication about handling and using the reusable boxes. Future research should study circulation of reusable packaging in higher cycles to properly assess the correlation between number of reuse cycles and packaging durability.

Future research could focus on translating this static representation into a processual step by step approach answering the questions of "*which assumption in which dimension should be addressed first?*" and "*can all the four dimensions be analysed simultaneously or in a specific order?*". As advanced research on sustainability assessment in the form of LCA studies is determined by the existence of reliable quantitative data, we suggest advanced sustainability assessment of reusable systems can only be developed at a later stage to generate reliable results. Similarly, assessing the viability of such reusable systems requires additional data on volumes, circulation rate, and number of cycles. Such assessment, therefore, requires carrying out more advanced and longer real-life pilots to gather required quantitative data. Future research could explore the priorities and order of experimentations to develop an efficient business model innovation process. As the case study solely focused on a reusable food take away packaging, it could be relevant to explore to what extent the findings can be extended to other reusable packaging segments.

CRediT authorship contribution statement

Anna Tenhunen-Lunkka: Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Angelos Balatsas-Lekkas:** Writing – review & editing, Writing – original draft, Visualization, Validation, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Erwan Mouazan:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Resources, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Sarianna Palola:** Writing – original draft, Investigation. **Tran Ngo:** Writing – original draft, Investigation. **Minna Salo:** Writing – review & editing, Writing – original draft, Validation, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Eveliina Hylkilä:** Writing – original draft, Investigation. **Henna Sundqvist:** Writing – review & editing, Writing – original draft, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Harri Luomala:** Writing – review & editing, Supervision, Methodology. **Kyösti Pennanen:** Writing – review & editing, Writing – original draft, Supervision, Resources, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Katariina Sorvari:** Writing – original draft, Investigation. **Päivi Petänen:** Writing – original draft, Investigation. **Jussi H. Lahtinen:** Writing – review & editing, Supervision, Project administration, Investigation, Funding acquisition, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

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