

# Preventing Single-Use of Plastic Packaging. Design Strategies for Circular Business Models: Refill, Reuse and Recycle



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**Abstract** The analysis of the plastic packaging value chain is fundamental to understand how to avoid the “end-of-life”, excess of recycled plastic, the logistics and new services among the supply chain, supported by the new technologies (e.g. IoT, AI, big data). Recognizing Earth as a limited source of resources and energy and looking at the waste and pollution as a potential and not as a defeat, are the foundations of the circular economy philosophy. Product design in particular, as well as business in general, are feeling an increasing pressure on moving from a linear to a circular approach to help reduce our global sustainability pressures [5]. Designers, innovators, and decision-makers in businesses, aim to become active actors on the necessary shift from an industry relying on fossil resources (Bakker, C. (2019). *Products That Last: Product Design for Circular Business Models*. Laurence King Publishing.). To give insights in the current product design and circular business model strategies able to promote the shift from a linear to a circular economy, preliminary interviews are presented as the first confrontation to a collapsible plastic bottle. The goal is to develop knowledge to support the framework to a more detailed research.

**Keywords** Product Design · Circular Economy · Plastic Packaging

## 1 Introduction

Moving from a linear economy to a circular economy have felt the combined effects of changes in design, rather than being destined for disposal, materials should maintain their utility and value and flow back into the cycle.

The transition to a business, which creates monetary and environmental benefits, has paved the way for the development of new business models focused on increasing resource efficiency, ensuring that the value of products, materials and waste is maintained.

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459

The relationship between design and actual success of business has been often addressed, nevertheless, the overall objective of this study is to explore design strategies related with the circular economy, where product-design is a source of innovation to business models, impacting on a system level, the plastic-packaging value chain.

This research explicitly addresses the problematic of the financial and environmental costs in transportation, storage and collection of blow-moulding plastic bottles, produced in a centralized business model.

Design strategies for circular business models may urge the plastic-bottles manufacturers to answer to their ownership obligations and shift from linear to a circular economy. This research focus on:

1. Avoid single-use of plastic bottles through refill and reuse.
2. Can design be a source of change to prevent single-use of plastic bottles?

It is important to understand the process of design for sustainability to find whatever implications may occur and what does centralized production means in the present design approach to circular business models.

## ***1.1 Motivation and Relevance***

Integrating circular economy principles in an early stage of the design process is important because once the product specifications are being made, only minor changes are usually possible. Ultimately, from general design parameters, innovation in products has to emerge taking into consideration human aspirations and worries – answering to a more participative, more environmental-conscient and more demanding end-user.

The circular business models are being advocated but yet they are not widely practiced. Today's world lives beyond large changes at topics such as industrial symbiosis, zero waste goals, non-energy industrial materials and biowaste, that influence all activity sectors, moreover the people day-by-day lives. The plastic manufacturers are one of the business stakeholders that are actually suffering large oscillations of environmental and societal paradigm.

“The anti-plastic sentiment is distracting us from the net environmental benefits of plastic relative to alternative materials when properly recycled” [23]. Replacing plastic with alternative materials such as paper and cardboard, glass, steel, aluminium, textiles, rubber, cork, results in a significant net negative environment impact [7, 23].

The plastic-packaging industry model is linear and dates from the Industrial Revolution. Plastic Packaging global economy develops around the model of consumption “take-make-use-dispose”, but various social, economic and environmental factors make it no longer sustainable.

## 2 Brief Literature Review

Recognizing Earth as a limited source of resources and energy and look at the waste and pollution as a potential and not as a defeat, are the foundations of the circular economy philosophy.

Product design in particular, as well as business in general, are feeling an increasing pressure on moving from a linear to a circular approach to help reduce our global sustainability pressures [5]. Designers, innovators, and decision-makers in businesses, aim to become active actors on the necessary shift from an industry relying on fossil resources. The selling drivers are now centre on generate services that profits from the flow of resources over time, continually reuse products and materials and using renewable energy [4].

### 2.1 *The Theoretical Foundation*

The origins of industrial ecology date from 1972, a global environmental movement started at the United Nations Conference on the Human Environment in Stockholm. Almost 30 years after the Stockholm declaration, General Motors published the paper “Strategies for Manufacturing” where the environmental impacts of manufacturing were discussed and the resources reduction and the waste accumulation were speculated [9].

“The traditional model of industrial activity ... should be transformed into a more integrated model: an industrial ecosystem. In such a system the consumption of energy and materials is optimized, waste generation is minimized, and the effluents of one process ... serve as the raw material for another” [15].

It was in a publication in 1994, in the fields of industrial ecology, where the idea of industrial metabolism was first presented [3]. The goal of industrial ecology was to achieve a state close to optimal, where nature prevails the most. Andrews [1] The industrial metabolism integrated all the industrial process that transform materials and energy, plus the labour inherent to those transformations, into products and industrial waste. A systematic approach that “complete or nearly-complete internal cycling of materials” [3].

#### **Systems approach**

Circular design involves many disciplines. Among them, the technical, financial and environmental fields, of the anthropology, the sociology, the ethical philosophy and design established an analogy between industrial and natural ecosystems [9].

In 2009, the book “Materials and the Environment: Eco-Informed Materials Choice”, written by the engineering professor Michael Ashby of Cambridge University, was a piece of evidence for the broad acceptance of the design contribution for the environmental strategies in business: eco-design [2].

In 2010, Jackson [9] definition of sustainability is one of the most succinct:

Sustainability is the art of living well, within the ecological limits of a finite planet.

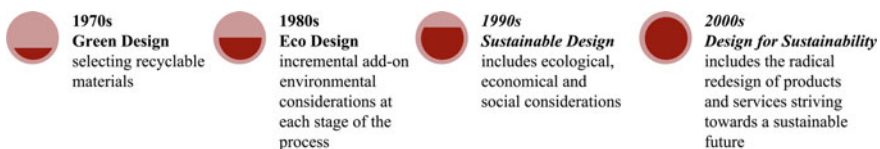
Below, is presented a historical review of industrial ecology main concepts, based on the paper “Industrial Ecology’s First Decade”: [17].

- **Life-cycle assessment (LCA)** is the methodology that seeks to identify the environmental impacts of a product or process at each stage of its life cycle.
- **Design for environment** consider environmental factors such as minimizing energy requirements, decreasing manufacturing discards, choosing more sustainable materials.
- **Material flow analysis (MFA)** is the methodology for quantifying the stocks, flows, inputs, and losses of resource.
- **Socioeconomic metabolism**, the ultimate task of this field of study is to relate resource transitions to societal change and to prospects for and measurement of sustainability.
- **Urban Metabolism** quantified flows of human and animal food, glass, plastics, sewage, sulphur dioxide emissions and the analyses of intensification of food, water and material consumption per capita.
- **Industrial Symbiosis** is the organization of industrial organisms and their processes so that “the waste of one process is the material for another”.
- **Circular economy** is an industrial system that is restorative or regenerative by intention and design. It replaces the ‘end-of-life’ concept with restoration, shifts towards the use of renewable energy, eliminates the use of toxic chemicals, which impair reuse, and aims for the elimination of waste through the superior design of materials, products, systems, and, within this, business models [10].

Today, the parallelism between the circular economy and design principles is fully assumed. In both disciplines, between the technical, economic and environmental fields; anthropology, sociology and ethical philosophy establish an analogy between industrial and natural ecosystems [9]. The acceptance that the activities of the man and society have a negative impact on the planet’s resources has been accepted for the first time by the user - the basic premise of sustainability.

Figure 1 represents the main moments of the historical evolution of environmental philosophies applied to design [19].

The circular approach evolves the end-user more than ever, especially in the elimination of waste, however, user awareness and contribution in a wide range of product lifecycle phases, or even by maintaining a more direct relationship with the manufacturers of the products (online shopping), is setting a rising trend of



**Fig. 1** Historical evolution of environmental philosophies applied to design [19]

direct participation on the shift to circular economy. Next section briefly explores the contemporaneous sentiment that has been rising in a modern consumptive but also highly aware society.

## 2.2 Anti-Plastic Sentiment

The confrontation with a continent size patch of garbage composed mainly of plastic floating in the Pacific Ocean produced the anti-plastic sentiment among our modern consumptive society. It highlighted, in fact, that much of the discarded plastic packaging is not actually reused or recycled, rather, it is disposed in landfills, ending-up in the ocean and other waterways, provoking large damage on Nature [8]. Environmental awareness has grown and raised around the world, an anti-plastic sentiment.

As can be seen in Fig. 2 the landfill disposal of solid plastic waste (SPW) in Europe has decreased by 38% between 2016 and 2014. In parallel, the SPW used for energy recovering and recycling increased 46% and 64%, respectively. An optimistic trend for the plastic industrial sector and for the consumers.

Moreover, despite the anti-plastic sentiment, plastic is also crucial as a circular recourse. Polymers melting temperature is about 300 °C, glass melting point is at 1600 °C. The energetic consumption is definitely outstanding. In the other hand, if we look at paper and cardboard as an alternative, the level of water consumption during and recycling is extremely high.

Those observations raise some issues about the fundamentals behind the anti-plastic sentiment and the ethics on the communication being done. And the pollution of the air and the water scarcity may be a bigger problem to face [22].

To look at the circular economy as a simple closing loop “take-make-use-recycle” may not be sufficient. The single-use policy [14] demands 90% separate collection target for plastic bottles by 2029 (77% by 2025), as well as a target to incorporate

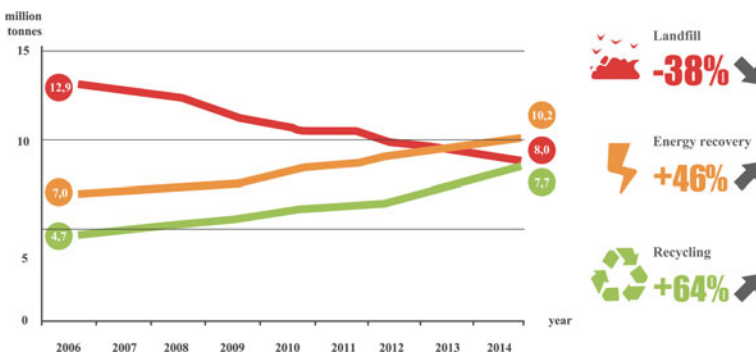


Fig. 2 Evolution of landfilling, recovery and recycling of SPW in EU [21]

30% of recycled plastic in all plastic bottles as from 2030 [14]. Furthermore, the annexe III of the European strategy for plastics set the target that 10 million tonnes of recycled plastics find their way into products in Europe in 2025 (4 million tonnes in 2016) [13].

The controversy is in increasing recycling as the main strategy to scale up the circularity of plastics, but the industry has no demand for all the recycled material [25] [22]. It is a capacity that nobody needs. Polyethylene terephthalate (PET), is already 100% recycled, and only in 10 years is expected to close the loop, since the stakeholders of the value chain need to adapt [25].

### 3 The Evidences of Plastic Paradigm

The main assumption that emerge from the literature review is that it will be required to understand the circular business models archetypes. It is crucial to generate guidelines that will draft the future recommendations to product design in general and in particular for the plastic industry. The transformation is needed to occur on a system and ecosystem level and not only on a product level, but the integration of circular economy principles in an early stage of the design process, with impact in all value chain, is fundamental to shift from a linear to a circular economy approach.

#### 3.1 *Gap in the Literature*

The plastic-packaging industry model of consumption is linear and dates from the Industrial Revolution. Plastic Packaging global economy develops around the model of consumption “take-make-use-dispose”, but various social, economic and environmental factors mean that it is no longer sustainable.

**Centralized production and air transportation.** The decentralization of the plastic packaging production (or in-hole production), by opposition to the centralized production, was a natural consequence of the regulation. However, that restriction is a demand for alimentary products. Meanwhile, the sustainable concepts have been generalized widespread, for market segments such as house-care and healthcare, the centralized production is still a common scenario nowadays for packaging of non-alimentary products.

This research explicitly addresses the problematic of the financial and environmental costs in transportation, storage and collection of blow-moulding plastic bottles, produced in a centralised model.

**Design for long-last, refill and reuse,** are huge challenges for plastic industry and for designers. To integrate circular economy principles in an early stage of the design process, because small changes made to existent products, serve a linear economy but it is no longer fitting the circular economy philosophy.

		Circular Business Models Archetypes				
Value Flows (adopted from Bocken et al. and Ellen MacArthur Foundation)		Primary Source of Revenue	Economic activities to Close Loops (Stahel)	PPS Business Models (Tukker)	Business model innovation to Slow & Close Resources Loops (Bocken et al.)	Business models for Circular Advantage (Accenture)
Services ↑	Slowing resources loops	<ul style="list-style-type: none"> <li>Profit from increased utilization rate of products, enabling shared use/access/ownership.</li> <li>Profit from selling access to a product for a specific period of time or 'uses and retaining material ownership.</li> <li>Profit from providing maintenance services or sales of refurbished, remanufactured or repaired units.</li> </ul>	Reuse and remarket of manufactured products	Result-oriented services	Access and performance model	Sharing platforms
	Cycling for longer	<ul style="list-style-type: none"> <li>Profit from repeated sales of consumables or services for a long-life product.</li> <li>Profit from selling high quality, high price products with a long lifespan.</li> </ul>		Use-oriented services	Extending product value	Product as a service
	Manufactures products ↓	Cycling for longer	<ul style="list-style-type: none"> <li>Profit from repeated sales of consumables or services for a long-life product.</li> <li>Profit from selling high quality, high price products with a long lifespan.</li> </ul>	Product-life extension activities products	Product-based services	Classic long-life model
Resources ↓			Product-life extension activities products		Encourage sufficiency	
					Extending resources value	Resources recovery
					Industrial Symbiosis	Circular Supplies

Fig. 3 Circular business model archetypes crossed with value flows

The plastic packaging value chain analysis is fundamental to understand: (i) how to end the “end-of-life” concept; (ii) how to avoid the excess of recycled plastic; (iii) the changes required in logistics and new services among the supply chain (e.g. take-back systems, remanufacturing technologies); (iv) how to use digitalization and new technologies (e.g. IoT, AI, big data) to support circularity.

**The categorization of circular business model archetypes** The chosen archetypes to the categorization of the circularity in the business models are based on the model presented in the Fig. 3, suggested by Moreno et al. [19] which crosses the value flows synthesized from Bocken [5] and Ellen MacArthur Foundation [10]. The choice was made to emphasize the manufacture of the product that integrates services in the value proposition (outlined in red, Fig. 3).

The methodology established consists of the analysis of three circular business models archetypes (refill, reuse and recycle), and position of the stockholders along the value-chain of a plastic-packaging, in a case study analysis.

### 3.2 Selected Model for the Analysis

In order to focus the analysis, the case study of WisePack is used. The principle of WisePack is the collapsibility of the packaging (Fig. 4) before the filling phase and after the use. Reducing transportation costs and the carbon footprint, as well as it facilitates its collection and reduce the contamination after usage, dropping the negatives impacts of the washing process [11, 12].

The research focuses on the activities or processes along with critical parts of the circular approach, to examine what are the requirements to upgrade efficiency and innovation capacity in the plastic packaging value chain through the design process. Promoting plastic packaging reliability, and duration through product-service systems (refill cycles, reuse and recycling).

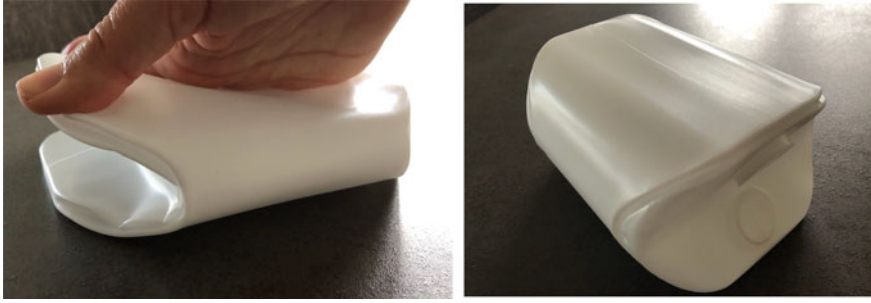


Fig. 4 WisePack functional prototype 2019

## 4 Research Structure and Methodology

This research problem aims to gain concrete, contextual, in-depth knowledge about the specific problem, such as WisePack that allows exploring the key characteristics and implications of the design in the context of circular business models (Fig. 4).

According to Sampieri, Collado and Lucio (2006), qualitative research gives data depth and a wide possibility of interpretation, as well as details and flexibility. The choice of different collection resources (Table 1) is due to the qualitative nature of the research and aim to raise information from different angles to understand the constraints and objectives among different stakeholders of the value chain.

The research structure is described below, and this article presents the findings from the preparation phase:

**Preparation relating theory** and problem delimitation: literature review and semi-structured interviews;

**Exploratory research** to uncovering new concepts and ideas that need to be incorporated: collective case study and value chain analysis;

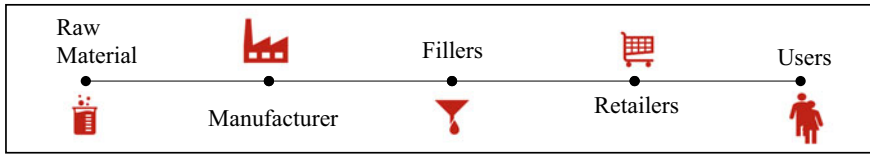
**Execution** exploring the design case through prototypes to verify (or not) the established assumptions: design conceptualization/ user behaviour driven;

A collective case study was selected in order to improve knowledge about the universe that the problem belongs. Gomm et al. [16] It aims to collect data that provide greater familiarity with the problem, with a more refined view in order to generate design ideas or identify constraints.

The first phase consists of the value chain analysis, aiming to identify the key-stakeholders and their constraints or requests that implicated the product or service design (Fig. 5).

The second phase of the exploratory research comprises semi-structured interviews with scientific experts, industrial association, manufacturers, fillers, retailers and end-users. Selltiz [24] The semi-structured interviews have been chosen, in order to obtain subjective information. Boni and Quaresma [6] Accordingly to Guerra [18],





**Fig. 5** The supply chain of the plastic packaging industry

“to protect sources” is important to “presupposing neutrality, confidentiality, clarity of ideas to be able to transmit them and generate valid results”.

The interviews were not conducted mechanically. This approach allowed spontaneous follow-up questions to be asked in order to clarify the details of the subject. The interviews ranged from 60 to 90 min. An overview of the conducted interviews is shown (Table 1).

The *interview script* has been completed over time and the order of the questions were not necessarily followed to maintain a fluid speech.

Interventions were reduced to a minimum and the content and language were kept true to the interviewees’ discourse [18] and translated into English whenever the interview was conducted in Portuguese. During the interviews, general aspects of the observed behaviours were collected and will be included in the next section.

#### 4.1 Results of the Interviews and Value Chain Analyse

Three major actions raised from the interviews and are the main required actions to promote the shift from a linear to a circular business model in the plastic packaging industry specifically (and plastic industry in general):

- (1) to increase collaboration of all value chain to develop waste-free design
- (2) to increase communication towards design for long-last, refill and reuse;
- (3) to reduce the dependency on fossil resources, introducing recycled resins.

In addition, a simplified life cycle assessment (LCA) emerged from the interviews, especially from the last interview mentioned in Table 1, the LCA researcher. This interview turned into a series of brief discussions about possible approaches for an LCA.

The extrapolation of the data extracted from the interviews and the researchers’ ethnographic analysis, suggested that a detailed LCA should be set aside at this stage. Due to the recognition that the reduction in volume during transport and the prolongation of the circulation time of each package (Fig. 6), are advantage known and accepted by all the stakeholders.

However, when the object of analysis is a specific packaging for a specific product and context of use, for a specific transition, an LCA analysis is recommended.

The relevant information to retain from this exploratory phase of the research is in one hand, that the ethnographic research conducted used interviews and observation

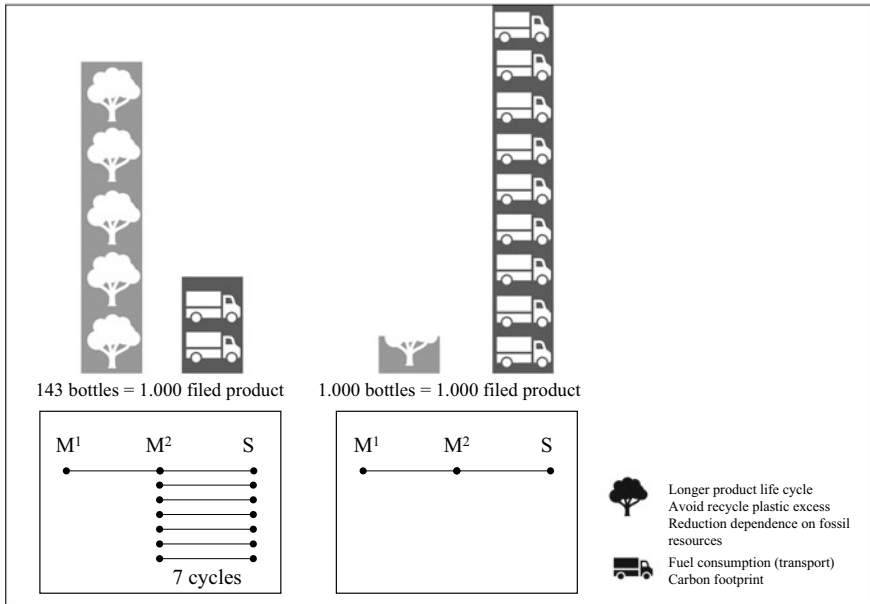
**Table 1** Overview of the conducted interviews

Type of organization	Design and Value Creation What is the first impression?	Process and Operations What are the key transformations?	Partners and network What are the key partners or channels?	Craving to innovate How does it promote innovation?	Perception and expectations What happened afterwards?	Reflection How do you think about it afterwards?
Manufacturer (centralized production) Portugal	.massive impact on final cost .environment is our priority	.possible to produce with the current machinery and materials	.other flexible need new processes/mach. .users are afraid of spilling chemicals (dislike flexible pack.)	.we need to differentiate, but only with realistic innovation	.we sell less .charge to license per each time the packaging is refilled?	.interesting, changes the geometry but not require significant investment on technology, material, machine or mold
Manufacturer (decentralized production) Portugal	.not interesting (...) reusable packaging goes against our business model	.hole-in-the-wall reduces shipping .weight reduction . incorporate PCR PET / HDPE	.work with key actors in the supply chain .incorporate recycled raw materials in customers products	. promote recycling . reduce the consumption of natural resources . help mold consumer's behavior	. implementation of deposit return systems .design and producing reusable packaging .reduce emissions and operational waste	.the shelf is very important, the contact with the end-user .prioritize recycling
Filler (production of goods) Belgium	.>3 liters avoid pet competition . >3 liters, the advantage of volume reduction	.identify big consumer problems and look for business and tech. partners	.work closely together along the plastic value chain (collection, transformation, marketing.	. disruptive approach that enables us to accelerate and elevate our R&D processes	.customer valorize environment less than product lower costs	.cooperation between stakeholders is key .work together along the plastic value chain

(continued)

**Table 1** (continued)

Type of organization	Design and Value Creation What is the first impression?	Process and Operations What are the key transformations?	Partners and network What are the key partners or channels?	Craving to innovate How does it promote innovation?	Perception and expectations What happened afterwards?	Reflection How do you think about it afterwards?
Retailer Portugal	.want to reduce the waste at our stores close to zero .wooding on ecodesign, looking for the best solutions	.understanding the client's needs and preferences, followed by a moment of experimentation	.promoting a stronger relationship between producers and academia and research centers	.products made from the surplus of the retail chain (...) made from end-of-life food products from our stores	.reduce, recycle and reuse or packaging its own brand plastic packaging, anticipating 2025 Sustainable Dev Goals	5 strategic pillars: .Energy & Climate Chan. .Circular Economy .Responsible Sourcing .Responsible Offer .Awareness & Education
Recycling Park Belgium	.package arrive broken, deformed	.all brands are collected together	.unaware of how others (recycle chain) proceed	.no innovation	.just waste .negligible value	.taxation based on weight or volume
Industrial Federation + Academic Expert Belgium	.citizens, need to simplification (IF)	.take-back process also impacts environment .each case needs an LCA (AE)	.it is difficult to motivate the take back . monetary incentive, as in glass bottles return on supermarkets	.it could use new materials, with sensors monitoring quality (IF)	.need policy development (AE) . IoT technologies can support the product- service design	.companies are very open to circularity, but their focus is economic benefits, not environmental



**Fig. 6** Ethnographic life cycle assessment emerged from the interviews

as the preferential interaction means. And on the other hand, may have changed some of the assumptions made from the representants of the different stakeholders of the value chain.

In order to better exemplify those contradictory assumptions, an additional diagram is presented (Fig. 7). The position of the icon indicating the filler (e.g. detergent producer), gives high weight to the “standing-out in the shelf and brand trust” as a relevance to the sales volumes. And this assumption is mostly due to the user criteria in the moment of the purchase, but the end-user or buyer, prints more weight into their decision based on price and waste-free packaging design.

It is interesting to see that the position of the user’s perception also favours environmental communication and the brand’s popularity. Adopting a clear position in favour of cost reduction and waste reduction.

In turn, in line with the initial assumptions based on the literature review, packaging manufacturers place greater emphasis on reducing transport costs due to the popularity of their brand and environmental marketing. And retailers place greater importance on the brand’s popularity, on environmental communication as a sales tool.

This cross-analysis will be addressed in further work. Namely, during the development of the case study and the scenarios description for circular business models. In addition, the analysis of the physical prototype during the interviews, stimulated a deeper understanding. This will also be validating the design requirements and

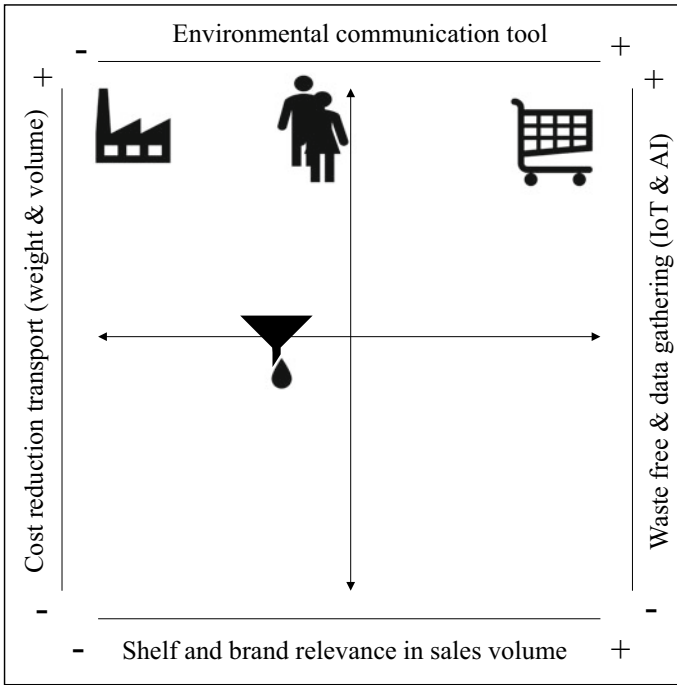


Fig. 7 Ethnographic assumptions emerged from the interviews

business points of view among the value chain, which will be fundamental to the delimitation of the research problem for a broader investigation.

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