PROPOSAL TO REDUCE ENVIRONMENTAL IMPACT THROUGH PACKAGING SYSTEM DESIGN

DESIGN DE SISTEMA DE EMBALAGEM PARA A REDUÇÃO DE IMPACTOS AMBIENTAIS

DISEÑO DE SISTEMA DE EMBALAJE PARA LA REDUCCIÓN DE IMPACTOS AMBIENTALES

CRISTIANE FERRARI ZENI, MSc. | UFRGS – Universidade Federal do Rio Grande do Sul, Brasil
RICARDO MARQUES SASTRE , Dr. | UFPR – Universidade Federal do Paraná, Brasil
ISTEFANI CARISIO DE PAULA , Dra. | UFRGS– Universidade Federal do Rio Grande do Sul, Brasil
AGUINALDO DOS SANTOS , Dr. | UFPR – Universidade Federal do Paraná, Brasil

ABSTRACT
One of the necessary steps for Packaging-Oriented Systems Design deals with mapping all packaging and accessories along a given value chain. This mapping covers the main filling, storage, and distribution flow, as well as its relationship with packaging levels and parallel flows, incorporated from other stages of the life cycle. These relationships can waste resources and cause environmental impact if they are not visible during the process. The objective of this article is to propose a framework to make the flow of artifacts throughout a Packaging System visible, with a view to reducing environmental impact. The framework was tested and evaluated in a dairy industry, resulting in a possible 20% reduction in packaging used to contain the same volume of product, if the improvements proposed from the study were applied. The method used was Design Science Research. The study contributes to advancing the understanding of the operationalization of Systems Design in the context of packaging, presenting the complexity of the relationship between the packaging and the product during its life cycle and its interactions with the companies' internal and external processes.

KEYWORDS
Systems Design; Environmental impact; Sustainability; Packaging system.

RESUMO
Uma das etapas necessárias para o Design de Sistemas Orientados para Embalagens lida com o mapeamento de todas as embalagens e acessórios ao longo de uma determinada cadeia de valor. Esse mapeamento abrange o principal fluxo de distribuição, armazenamento e distribuição, bem como sua relação com os níveis de embalagem e fluxos paralelos, incorporados de outras etapas do ciclo de vida. Essas relações podem desperdiçar recursos e causar impacto ambiental se não forem visíveis durante o processo. O objetivo deste artigo é propor uma estrutura para tornar visível o fluxo de artefatos ao longo de um Sistema de Embalagem, com vistas à redução do impacto ambiental. A estrutura foi testada e avaliada em uma indústria de laticínios, resultando em uma possível redução de 20% nas embalagens usadas para conter o mesmo volume de produto, caso as melhorias propostas a partir do estudo fossem aplicadas. O método utilizado foi Design Science Research. O estudo contribui para o avanço da compreensão da operacionalização do Design de Sistemas no contexto das embalagens, apresentando a complexidade da relação entre a embalagem e o produto durante seu ciclo de vida e suas interações com os processos internos e externos das empresas.

http://dx.doi.org/10.29183/2447-3073.MIX2023.v10.n2.197-209
ISSN: 2447-0899 (IMPRESSA) | 2447-3073 (ONLINE)

PALAVRAS-CHAVE
Design de Sistemas; Impacto ambiental; Sustentabilidade; Sistema de embalagem.

RESUMEN
Uno de los pasos necesarios para el Diseño de Sistemas Orientados a Embalajes trata del mapeo de todos los embalajes y accesorios a lo largo de una cadena de valor determinada. Este mapeo cubre el flujo principal de llenado, almacenamiento y distribución, así como su relación con los niveles de embalaje y flujos paralelos, incorporados desde otras etapas del ciclo de vida. Estas relaciones pueden desperdiciar recursos y causar impacto ambiental si no son visibles durante el proceso. El objetivo de este artículo es proponer un marco para hacer visible el flujo de artefactos a lo largo de un Sistema de Embalaje, con miras a reducir el impacto ambiental. El marco fue probado y evaluado en una industria láctea, resultando en una posible reducción del 20% en los embalajes utilizados para contener el mismo volumen de producto, si se aplicaran las mejoras propuestas a partir del estudio. El método utilizado fue Design Science Research. El estudio contribuye a avanzar en la comprensión de la operacionalización del Diseño de Sistemas en el contexto de los embalajes, presentando la complejidad de la relación entre el embalaje y el producto durante su ciclo de vida y sus interacciones con los procesos internos y externos de las empresas.

PALABRAS CLAVE
Diseño de Sistemas; Impacto ambiental; Sostenibilidad; Sistema de embalaje.

1. INTRODUCTION

Packaging throughout its history has represented an important tool for the commercial development and growth of cities, as it ensures that the product reaches the end consumer in safe and quality conditions. It is the result of the action of a complex and multidisciplinary system, made up of the actions of several specialists who develop complementary activities, such as researchers, designers, operators, among others involved in its conception (ROBERTSON, 2013; SASTRE et al., 2019).

A company's Packaging System (PS) is conventionally understood as a set of processes, materials and technologies used to package, protect, distribute, and market the products that the company manufactures or sells (CABRAL; CABRAL, 2010). From this perspective, when well designed and adapted through the integrated process of packaging, product and logistics development, opportunities are achieved to save resources, reduce environmental and commercial costs, and increase efficiency throughout the chain (MOLINA-BESCH; PÅLSSON, 2014). The PS can be understood as composed of several intertwined flows (MUNIZ; POSSAMAI, 2019), being designed to serve many contexts that interact in a complex way (BARABASI, 2005). Design decisions regarding the type of material and format, for example, can impact the primary function of packaging, affecting the stages of production, distribution, commercial actions, use and disposal by consumers and, ultimately, causing damage to the environment.

Designing packaging-oriented systems involves considering aspects such as the profile of the actors required in the system, as well as the configuration and dynamics of process and operations flows, in addition to the portfolio of packaging and associated services. From the perspective of the Production Function Mechanism, proposed by shingo (1989) the analysis of flows within a packaging-oriented system needs to start with the "process", that is, with the flow of materials and/or information. Analysis of the flow of operations (people or machines) must be carried out after analyzing the process.

Due to the significant representation of packaging as a source of waste generation on the planet, company managers are seeking to outline strategies to prevent and, when this is not possible, reduce its demand. Such efforts require an accurate analysis of the points of presence of waste and environmental impacts during the process. In this way, the application of the contemporary perspective of sustainability demands that the ES contemplates the social, economic, and environmental dimensions concomitantly. In this sense, it is considered that developing an ES with superior environmental performance cannot necessarily be considered sustainable (DE KOEIJER; DE LANGE; WEVER, 2017). It is observed that the search for improving the environmental performance of packaging often emphasizes the use of non-toxic, renewable, local, and recyclable materials. The selection of these materials and respective processes requires carrying out life cycle assessments (LCA) that support the decision process to minimize the ecological footprint.

From an economic perspective, a PS contemplates not only issues of a financial nature, including criteria such as equity between actors, encouraging local entrepreneurship, prioritizing network organizations, sharing local assets, among other aspects. From a social perspective, the PS needs to consider mechanisms for integrating the weak and marginalized, respect for local culture, the promotion of social cohesion, equipping consumers to make socially fair and ethical choices (ABDUL KHALIL et al., 2016; BESIER, 2015; PETLJAK; NALETINA; BILOGREVIĆ, 2019).

That said, the skills required of professionals working in the packaging sector transcend the limits of packaging itself. With the purpose of contributing to a better understanding of these skills, this research proposes to answer the following question: how to identify losses related to packaging in the production system with the aim of identifying opportunities for improvement and reduction of environmental impact? The objective of this article is to propose a framework to make companies' packaging systems visible with a focus on reducing environmental impact.

2. PACKAGING-ORIENTED SYSTEMS DESIGN

This section describes the theoretical references relating to the construction of the proposed framework, based on the vision of integration between the packaging and product life cycle, as well as the packaging classification and the definition of the Packaging System.

2.1 Integration between the packaging and product life cycle

The starting point of the life cycle is the extraction of raw materials from nature and their subsequent transformation for use in packaging. The third stage deals with the design phase: the logical and creative conception of the packaging (structural and graphic) carried out by a studio, design agency or internal project team within the company, which will subsequently forward it to the packaging industry. In some cases, the packaging industry itself adapts the design to available matrices. Next, the packaging manufacturing phase. It can be said that the continuity of the packaging life cycle overlaps with the life cycle of the product for which the packaging was designed, and this overlap occurs from the filling phase onwards (Figure 1). The sales/distribution phases can occur in different ways, whether on a supermarket shelf or e-commerce, for example. The use phase is when the consumer meets the packaging. Finally, the packaging is discarded, treated, and sorted. When previously viewed by the designer from a systemic perspective, the life cycle phases generate the opportunity for action to close the cycle in a sustainable way. In this case, the packaging may be returned to the factories and recycled or another procedure that extends its useful life (reuse, remanufacturing) (JANG et al., 2020). There is also the possibility of returning the packaging to the natural system, when it is compostable (CASAREJOS et al., 2018).

It is important to highlight that packaging has its own life cycle, whether primary, secondary or others. Even though they are an integral part of a product (product--packaging system), the cycles of both run in parallel until they overlap after packaging and may separate again after the product is used (Figure 1). When a product reaches the end of its useful life, it must be separated from its packaging so that appropriate treatments can be given to both. Post-use or end-of-life costs are also related to reverse logistics for treatment and final disposal purposes.

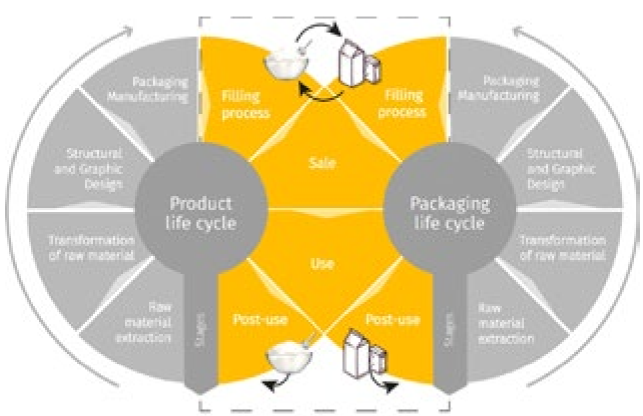

Figure 1: Overlap between packaging and product life cycles.
Source: by the authors.

In the view of the authors of the present study, the Packaging System is located exactly in this overlap between the life cycle of the product and the packaging, requiring extensive knowledge of the technical characteristics and limitations of the production lines and equipment involved, as well as the processing processes. distribution, sale, use and post-use of products and their packaging.

Although physically the superposition generally occurs from the filling phase (Figure 1), from the first phase (definition of the packaging raw material), it is necessary to evaluate the nature of the product's raw material, for the purposes of evaluating compatibility between packaging material and product material that will be sent to the filling process. This is essentially relevant when the material being filled is in a liquid or semi-solid physical state, as the chances of chemical interactions between the packaging wall and the filled material are more likely (SZCZEPAŃSKA; KUDŁAK; NAMIEŚNIK, 2018).

Molina-Besch e Pålsson (2014) suggest that companies along the supply chain must align their objectives and integrate resources related to packaging so that it provides maximum value to all actors in the supply chain. A prerequisite for sustainable supply chains is that companies systematically consider relevant logistical aspects during the packaging development process. The authors Molina-Besch and Pålsson (2014) list 4 integrative elements of packaging development processes as relevant to the sustainability of supply chains:

- **Integration with product development -** because product and packaging are transported, stored, and handled together in many parts of the supply chain, an integrated product and packaging development process is required.
- **Integrated development of packaging system levels -** the different levels of a PS can be developed successively from one end or in an integrated approach, in search of system optimization.
- **Cross-process functionality -** if PS are to be adapted to different requirements along the supply chain, the packaging requirements of different actors must be considered systemically.
- **Involvement of external supply chain actors -** to consider the external aspects of the company's supply chain, external supply chain actors must be consulted and involved in the packaging development process.

https://doi.org/10.29183/2447-3073.MIX2023.v10.n2.197-209

Decisions related to packaging development (size, material, format, etc.) and their interactions throughout the entire life cycle (product protection, consumption method, disposal method, etc.) can minimize the environmental impacts of the packaging. packaging-product system and promote a Circular Economy when the project includes appropriate materials and processes, ensuring the desired protection for the product, without excessive consumption of material and with the revaluation of post-consumer material (ABRE, 2016).

2.2 Packaging classification

Packaging in general can be classified as primary, secondary, and tertiary (BRISSON, 1993; CARVALHO, 2008; MAHMOUDI; PARVIZIOMRAN, 2020a). The primary ones are those used by the industry when packaging the product (lid, bottle, and label). Secondary packaging is consumer packaging, those that are in contact with the user and displayed at the point of sale. Transport packaging is tertiary and contains all the previous elements in an organized manner (CARVALHO, 2008; HELLSTRÖM; NILSSON, 2011; MAHMOUDI; PARVIZIOMRAN, 2020b; MOURA; BANZATO, 1997). According to Hellström and Nilsson (2011), this classification is used when considering packaging as a system and illustrates the packaging components and hierarchy levels (Figure 2).

Figure 2: Packaging classification
Source: by the authors.

For reasons of safety and maintaining the integrity of the product, some components are used, such as angles and plastic films for pallets, or even a cradle can be adopted inside the consumer packaging to ensure that the bottle will not suffer any damage during transportation breakdown, for example. In some cases, transport packaging serves as consumer packaging. This occurs in larger products, such as household appliances and machines. Expanding this classification, we present fourth-level packaging, which facilitates movement and storage in transport, and fifth-level packaging, used for long-distance shipments, such as containers (MOURA; BANZATO, 1997). Each level of importance and the functions that packaging fulfills in packaging products will determine the type of solution to be adopted.

From a sustainability point of view, it is understood that good projects must replace or minimize the profusion of packaging levels throughout logistical processes, since their useful life is usually short and they are not always produced in a sustainable way (MAHMOUDI; PARVIZIOMRAN, 2020b). It also affects environmental performance in terms of waste handling and filling rates in transport. Therefore, in a Packaging System with different levels, the functions must be seen from the perspective of the system. This means that it is the entire system that must, for example, protect the product. Thus, enhanced protection of secondary packaging can reduce the level of protection required in primary packaging and vice versa, depending on the context (PÅLSSON; HELLSTRÖM, 2016). Therefore, the reuse of secondary, tertiary and higher levels of packaging is advocated, from a perspective of circularity and extension of useful life (SELVIARIDIS et al, 2016).

2.3 Packaging System

The Design of a Packaging-oriented System deals with the configuration of the actors and the dynamics of the respective flows (materials, information capital, services). The conventional perspective is more restricted regarding PS, considering only the set of processes, materials and technologies used to package, protect, distribute, and sell the products that the company manufactures or sells (CABRAL; CABRAL, 2010). For Moura and Banzato (1997), a Packaging System is an interrelated set of operations and materials necessary to move products from the point of origin to the point of consumption, including machinery, equipment, and vehicles for their shipment (MOURA; BANZATO, 1997). The authors also define that, as in all systems, the parts are numerous and diverse, and all "decisions made and implemented at the level of one component cause ramifications at other levels" (MOURA; BANZATO, 1997).

When the material and information flows of an PS are designed appropriately, the elimination or mitigation of environmental impacts, equity and social cohesion, in addition to equity and economic justice are achieved. From an operational perspective, the industry can save resources by reducing materials, optimizing space, reducing damage and losses, distributing efficiency, and incorporating sustainable practices. At the highest level, the system can include strategies that result in the prevention of the use of packaging, such as the digitalization of products, the servitization of consumer relations, the encouragement of the sharing economy, as well as social and lifestyle innovations that can completely suppress the demand for packaging. In this sense, in cases where strategies aimed at preventing consumption are more restricted, it is possible to integrate logistical and supply chain considerations into the packaging development process, seeking to minimize and optimize resources, bringing not only economic benefits to companies, but also opportunities to reduce environmental and commercial costs and increase efficiency throughout the chain (MOLINA-BESCH; PÅLSSON, 2014).

However, Palsson et al. (2013) shows that current models and methods used to support packaging selection in manufacturing companies rarely consider sustainability dimensions. Furthermore, they often do not reflect the entire supply chain, as assembly and material supply systems are largely designed separately, which leads to sub-optimization. To avoid it and facilitate an integrative approach to assembly and material supply systems, packaging can play a key role, as there are several interactions between packaging and logistics along the supply chain. Molina-Besch and Palsson (2014) consider that packaging is a central component in logistics, as it adds weight and space to products during handling and transport, but also facilitates the use of volume due to the stacking capacity and efficiency of packaging. handling. At workstations relevant to the assembly of packaging and insertion of products to be transported/protected, it is possible to obtain considerable time and cost savings by adjusting the packaging system to the assembly situation in question and the components used (PÅLSSON; FINNSGÅRD; WÄNSTRÖM, 2013). In this way, packaging has a direct impact on the energy use of transport, handling, and storage processes, in addition to influencing the amount of product waste throughout supply chains (MOLINA-BESCH; PÅLSSON, 2014). Furthermore, it has other functions of great importance, such as being a potential driver of consumer education and reinforcing people's connection to the culture of a territory.

In short, a Packaging System (PS) encompasses all aspects related to packaging in its life cycle, from the selection of raw materials to the design, distribution, and post-use processes. Decisions and assessments involving packaging require a holistic approach that considers all parts of the supply chain. Packaging must be understood as a complex system that encompasses predictable and/or unexpected interactions between its parts and processes, therefore requiring permanent attention to the whole and each of its parts throughout its life cycle, to can be managed efficiently and effectively (CABRAL; CABRAL, 2010; SASTRE et al., 2019).

3. RESEARCH METHOD

Aiming to develop an instrument to make companies packaging systems visible with a focus on reducing environmental impact, three stages of the Design Science Research methodology based on Dresch were used; Lacerda; Cauchick (2019). Design Science is the science that seeks to consolidate knowledge about the design and development of solutions to improve existing systems, solve problems and create artifacts DRESCH; LACERDA; JUNIOR, 2015). Implementation is part of a development cycle that must be tested and converge to a result at each stage, until reaching final verification, through validation of the artifact's usefulness. The procedure developed in the three stages shown in Figure 3.

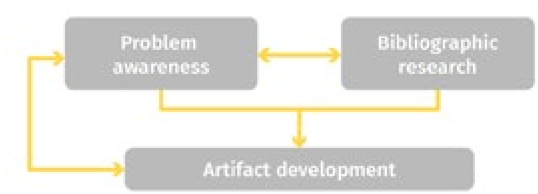

Figure 3: DSR steps adopted.
Source: by the authors.

3.1 Problem awareness

At this stage, consultation began with literature reference bases and the construction of knowledge related to the integration between the packaging and product life cycle, the definition of PS and in which context it is inserted, as well as problems, waste and impacts caused by packaging in its chain. Preliminary searches were carried out in books and articles randomly and search string tests were carried out for the literature review. After the preliminary search, articles, and books relevant to the topic were grouped in Mendeley (reference management software), read, and analyzed by the authors. The authors visited two companies and carried out a preliminary mapping of their Packaging Systems to verify their performance in practice. Raising awareness of the problem initially had the purpose of surveying the topic in the literature and within companies.

3.2 Bibliographic research

This stage required a bibliographical review, with emphasis on books, magazines, standards, theses, and dissertations, as well as technical materials available on the internet. The chosen string was composed of the keywords and Boolean operators "Packaging and supply chain integration and Sustain*". The research base was the Web of Science. The search resulted in 66 articles on the topic, of which 22 articles were selected for full reading. During the systematic literature review, other articles referenced in the text were extracted (unsystematic literature review) and incorporated into the reference base of the present study.

The purpose of the literature review was to identify theoretical content that the designer needs to access to develop a PS that meets design requirements, reduces environmental impact, and meets the needs of stakeholders. This review was necessary to organize the theoretical framework to compose the proposed framework. The content of the reference model was structured based on context units and analysis units. The context units were those related to the conditions or phases of the life cycle in which the packaging may be inserted. Units of analysis refer to guiding elements that can be applied to context units.

3.3 Artifact development

For the development of the artifact, relevant contents were defined to compose the graphical representation of the framework and based on these, the functions it should fulfill. The contextual structure defined for the framework was supported by the integrated phases of the packaging and product life cycle, organized according to the logic of the circular economy. It should be noted that the visual model was developed based on the packaging, sale, use and post-use process phases. Following an abductive logic, the elements contained in the framework were designed using information extracted from the literature.

The artifact was evaluated by the authors and 2 experts (product designer specializing in packaging projects and doctor in production engineering specializing in sustainable product design). A 3-hour meeting was held with the 2 experts, the debate was recorded, transcribed, and later analyzed.

The framework was tested in one company a manufacturer in the dairy sector. To this end, the product manufacturing, packaging, storage, distribution, and sale processes were observed and mapped. At the same time, interviews were carried out with managers and operators from all sectors related to the processes. In the end, PS maps and reports with opportunities for improvement were generated, which were discussed and validated with company managers. The experts reflected on the particularities of the cases and their influence on the framework, searching for patterns that serve the different cases.

4. RESULTS AND ANALYSIS

Figure 4 presents the proposed framework to make companies Packaging System visible. The model helps to facilitate the identification of opportunities for improvements in PS with a focus on reducing environmental impact through the analysis of losses in the company that manufactures a given product. The objective of this framework is to make visible the generation and disposal of process packaging waste, product components and inputs, from product manufacturing to distribution, transportation, sales, use and disposal at the end of its useful life, both in processes internal and external to the company.

The internal processes, in gray, begin with the manufacturing of the product and end in the quaternary packaging, where distribution begins. Processes external to the company, in brown, continue until the post-use stage. The result of the framework can be seen in figure 4, and the detailed description of each part that makes it up can be understood below. In figure 5, a schematic representation of the framework can be seen, highlighting the convergent PS that start outside the company's flow (starting from the production flows of input and packaging suppliers) and end up generating waste that becomes the company's responsibility.

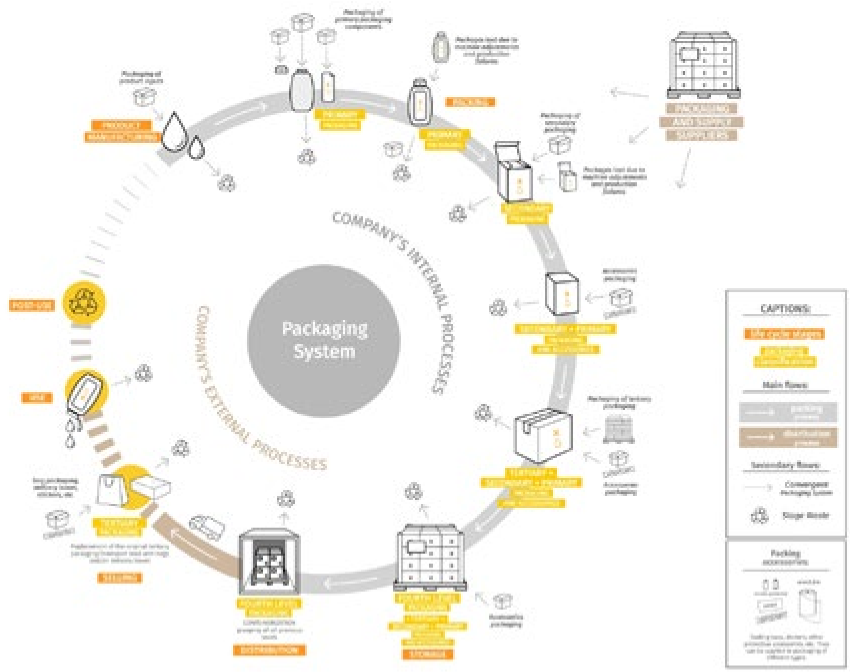

Figure 4: Packaging System Framework.
Source: by the authors.

The elements contained in this graphic representation are essential for understanding the possible waste and environmental impacts caused during the product manufacturing and distribution process.

- **Internal and external processes:** Internal processes, represented in gray, refer to the operations and sectors directly involved with packaging, where the company has greater autonomy in the case of decision-making, such as the internal production, planning and control sectors production (CSP), environmental engineering, inventory, shipping, quality, purchasing, commercial, among others. External processes, represented in brown, are interactions in the life cycle in which the industry has less autonomy in decision-making, as well as less process traceability, such as packaging and input suppliers, distributors, transport companies, points of sale, end consumers, sorting cooperatives, among others. The brown color is represented in solid color until sale, where it takes on a spaced format that becomes increasingly dispersed as it approaches post-use, to demonstrate that the company normally loses control and tracking over these stages.

- **Packaging and product life cycle:** The life cycle stages, in orange, are important to obtain an overview of the process and at the same time meet the design and production demands in each of them. The flow representation in gray shows the product filling and storage processes and, in light brown, the distribution, sale, use and post-use processes.

- **Packaging classification:** The types of packaging and components (in yellow) used throughout the process must be mapped in their entirety to make it possible to analyze the usefulness of each part, as well as proposed replacement or elimination of packaging levels and/or or components used, such as: angles, adhesive tapes, plastic films, among others.

- **Convergent packaging systems:** The supply of each component or input for packaging and product manufacturing is delivered in packaging and incorporated into the production process. These items become the responsibility of the company, which needs to define their disposal. Therefore, the framework highlights that there are these items that come from outside the process and are discarded within the company, to help decide with input suppliers how to reduce or eliminate packaging or improve their recycling value.

- **Waste generated:** During the filling and distribution process, a lot of waste ends up being generated, such as: empty packaging, adhesive tapes, plastic films, adhesive liners, tubes, pallets, packaging damaged in machine setup, excess product protection, inadequate storage, among others. It is important to identify them to act promptly in each situation, proposing improvements and reductions.

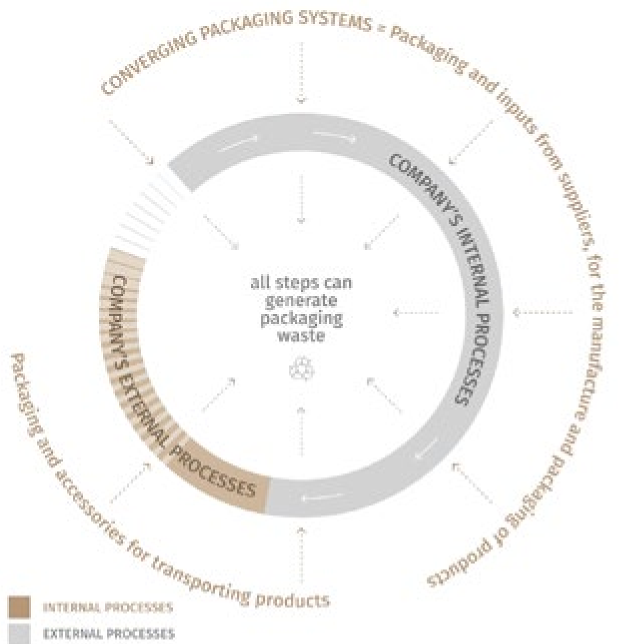

Figure 5: Schematic representation of the PS framework.
Source: by the authors.

In this representation, all stages of this process generate packaging waste, whether due to the disposal of input packaging, or losses in the process (losses due to machine adjustments, handling failures, breakdowns, etc.). Furthermore, at almost every stage there is a convergence of the SP of the inputs, which become waste under the responsibility of the company that is using these inputs. Observing PS in companies, one can see how natural it is for employees to use these packaging and subsequently discard them to the recycling sector. Therefore, the representation shows that these come from outside the process, and are discarded within the cycle, within the company. Likewise, the use of accessories, such as adhesive tapes, lamination (stretch film), corners, among others, also became more evident.

The sales channels where the product will be sold, as well as the use of the product by the consumer, also influence the product design and packaging requirements, which end up impacting the processes. It is important to highlight that at the sales stage it was observed that, in addition to the disposal of tertiary and higher level packaging, there is also the addition of new packaging in the cycle, such as bags for the customer to transport the product from the store to their home, or boxes of transport to send products via e-commerce, for example, generating yet another packaging disposal. Furthermore, in the product use stage, all packaging that reaches the consumer is discarded, this being the most criticized point in terms of sustainability as it is the most visible to consumers, who are responsible for separating waste and disposing of it appropriately. to collection points for recycling. Finally, the framework highlights suppliers of packaging and inputs, which are essential in the cycle.

The elements contained in this graphic representation help to understand the possible waste and environmental impacts caused during the product manufacturing and distribution process. The companies Packaging System is unstable and is in constant movement, as new analysis and mapping needs may arise in each application situation. The proposal presented the main points to be observed during this process. The following presents the application of the framework during the study carried out by the project team.

4.1 Artifact validation

The framework was tested in a dairy company in the state of Goiás through a study carried out in March, April, and May 2023. The main objective was to map the company's Packaging System, aiming to reduce costs and environmental impact. In the first stage, an immersion in production was carried out to follow the processes from the entry of raw materials to the finished product upon dispatch. Through observation and interviews with managers from the areas in which the packaging participates (internal stakeholders), an infographic was developed containing all the packaging and components used in each production line. Based on the structure proposed in figure 4, the PS was analyzed following the same order. The analysis resulted in the graphic representation presented in figure 6, developed from a production line from this company, responsible for packaging culinary bases for other food industries (B2B).

Packaging and product life cycle: The product is manufactured by mixing ingredients in aluminum tanks in the UHT (Ultra High Temperature) process and sent to the filling equipment via piping. The machine fills the product by automatically opening and closing the packaging, which, using a conveyor belt, is directed to packaging in shipping boxes, for subsequent stacking on pallets. The complete pallet is sent to another sector that adds angles, identification labels for the carrier and stretch film. After this process, the product is collected on the same day it was produced and sent to the customer via third-party carrier.

Classification of packaging: The production line analyzed uses multilayer bags as primary packaging, with identification on an adhesive label; the secondary ones are cardboard boxes for stacking and transporting the bags (2 bags of 10L or 4 bags of 5L per box); At the tertiary level, palletization takes place, using adhesive tape, angle irons, plastic sheets, stretch film and a cardboard base between the product and the pallet.

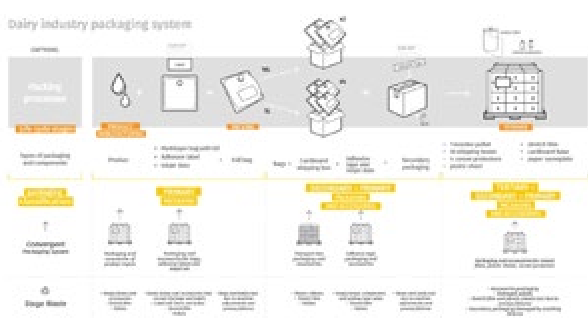

Figure 6: Design of the Packaging System for a dairy industry.
Source: by the authors.

Internal and external processes: In the scenario of the analyzed company, the internal sectors involved with this production line are purchasing, shipping, production, R&D, warehouse, SAC, and quality. The external processes observed were filling system supplier (responsible for equipment and packaging supply), transport companies and input suppliers.

Convergent packaging systems: All packaging from product manufacturing input suppliers were mapped. An accumulation of empty packaging, pallets, components, and accessories used to contain and transport inputs was noticed. A meeting with suppliers was suggested to propose a complementary study for their PS, with the aim of evaluating the reduction in the amount of packaging and the use of raw materials with greater recycling value.

Waste generated: The waste generated during the manufacturing process was, for the most part, empty boxes, adhesive liners and stretch film coming from various input suppliers. In this case, the loss of primary packaging during machine setup is practically zero, as the filling system does not waste packaging during setup or product change. Some cardboard boxes and bags were lost due to damage during palletizing and internal movement of the finished product.

The solutions for reducing waste and environmental impact in the analyzed production line were presented and validated with the company's management, they are: the increase of 1 liter of product per bag, since the internal free space (headspace) was greater than as necessary, without compromising the performance of the product and packaging in its chain, and providing a 20% reduction in packaging used to contain the same volume of product monthly; reduction in the size of the identification label; resizing of shipping boxes; replacing paper angles with molded pulp (made by reusing scraps) and reducing the number of layers of stretch film to protect the stacking of palletized products.

5. FINAL CONSIDERATIONS

The present study was designed based on the theoretical-practical experiences of the authors, through an in-depth study of the literature and consultancy work on Packaging Systems in industries, using and improving the proposed framework. Answering the research question: how to identify losses related to packaging in the production system with the aim of identifying opportunities for improvement and reduction of environmental impact? The proposed framework contributed to making visible the totality of packaging and components within the system, as well as the converging systems of input suppliers, the step-by-step process of each stage of the life cycle and the waste generated during each stage in the integration between packaging and the product.

It is understood that this study encourages a systemic view of packaging processes, being an initial tool for analyzing waste that may be occurring within product manufacturing companies and/or packaging companies. Other support tools, metrics and indicators for evaluating the improvements implemented, sectors and stakeholders to be analyzed throughout the study must be customized according to the types of products, processes and company context. This is because we sought to develop the framework so that it was applicable to companies from different segments and regardless of their specific characteristics.

Packaging should be analyzed as key elements in production and logistics processes, as they accompany the product from the point of packaging to the point of consumption. Throughout the study, it was possible to observe that, in addition to better organization of processes and cost reduction, the identification of waste of resources that emerge throughout the PS mapping can guide the company to the incessant search for incremental and continuous improvements in processes. organizations in a systematic and constant way, allowing to achieve increasingly higher levels of efficiency and quality. For example, in the dairy industry it was possible to identify an opportunity to reduce packaging used to contain the same volume of product by 20%, if the improvements proposed from the study were applied.

Proposed changes can range from the physical reorganization of workstations to the implementation of new technologies to speed up the packaging process. Monitoring and measuring the impact of these changes through key performance indicators allows for an objective assessment of the results achieved. Furthermore, engaging the entire packaging team in this evaluation process makes it possible to collect valuable insights from those directly involved in the workflow. Recognizing individual contributions and encouraging the presentation of improvement ideas creates an environment conducive to innovation and evolution of packaging processes. Expanding the possibilities of actions to reduce environmental impact, it is recommended to rethink packaging projects at one or more levels (primary, secondary, tertiary, etc.); change packaging and handling processes for goods; evaluate the exchange of materials, production processes and packaging suppliers; readjust distribution and logistics systems; eliminate packaging components and properly dispose of pre-consumption waste. Understanding that packaging is part of a life cycle and that there are many elements involved to be considered is the way to promote sustainability in packaging.

Therefore, this study reinforces the fact that investing in the organization and effective mapping of Packaging Systems represents not only an operational strategy, but also a commitment to the sustainability and global effectiveness of industrial practices. Finally, it is recommended as future studies the integration of other support tools, coming from different areas of knowledge, such as: Lean manufacturing, Product-Service System (PSS), the principles of the circular economy, the analysis of the packaging system and from economic and social perspectives, among others.

REFERENCES

ABDUL KHALIL, H. P. S. et al. A review on nanocellulosic fibres as new material for sustainable packaging: Process and applications. **Renewable and Sustainable Energy Reviews**, v. 64, p. 823–836, 2016.

ASSOCIAÇÃO BRASILEIRA DE EMBALAGEM. ABRE. **Embalagem e sustentabilidade: desafios e orientações no contexto da economia circular.** 1ed. SãoPaulo: CETESB, 2016.

BARABASI, A.-L. The architecture of complexity. p. 3–3, 2005.

BESIER, S. Generational perceptions of pro--environmental packaging advantages. **uwf UmweltWirtschaftsForum,** v. 23, n. 4, p. 315–322, 2015.

BRISSON, I. Packaging waste and the environment: economics and policy. **Resources, Conservation and Recycling,** v. 8, n. 3–4, p. 183–292, 1993.

BUCCI, D. Z.; FORCELLINI, F. A. Sustainable packaging design model. Complex Systems Concurrent Engineering: Collaboration, T**echnology Innovation and Sustainability**, v. 55, n. 47, p. 363–370, 2007.

A. C. CABRAL;, & D.B. CABRAL. (2021). Gerenciamento sistêmico de embalagem em indústrias fabricantes de bens de consumo. XXX ENEGEP, 2010.

CARVALHO, M. A. Engenharia de embalagens: uma abordagem técnica do desenvolvimento de projetos de embalagem. 1. ed. São Paulo: Novatec, 2008.

CASAREJOS, F. et al. Rethinking packaging production and consumption vis-à-vis circular economy: A case study of compostable cassava starch-based material. **Journal of Cleaner Production,** v. 201, p. 1019–1028, 2018.

DE KOEIJER, B.; DE LANGE, J.; WEVER, R. Desired, perceived, and achieved sustainability: Trade-offs in strategic and operational packaging development. **Sustainability (Switzerland)**, v. 9, n. 10, p. 1923, 2017.

DRESCH, A.; LACERDA, D. P.; JUNIOR, J. A. V. A. Design Science Research. 1. ed. Porto Alegre: [s.n.], 2015.

DRESCH, A.; PACHECO LACERDA, D.; CAUCHICK-MIGUEL, P. A. Design science in operations management: conceptual foundations and literature analysis. **Brazilian Journal of Operations & Production Management**, v. 16, n. 2, p. 333–346, 2019.

HELLSTRÖM, D.; NILSSON, F. Logistics-driven packaging innovation: A case study at IKEA. **International Journal of Retail & Distribution Management**, v. 39, n. 9, p. 638–657, 2011.

JANG, Y. C. et al. Recycling and management practices of plastic packaging waste towards a circular economy in South Korea. **Resources, Conservation and Recycling**, v. 158, n. February, 2020.

MAHMOUDI, M.; PARVIZIOMRAN, I. Reusable packaging in supply chains: A review of environmental and economic impacts, logistics system designs, and operations managementInternational J**ournal of Production EconomicsElsevier** B.V. 2020a.

MOLINA-BESCH, K., & PALSSON, H. Packaging for eco-efficient supply chains: Why logistics should get involved in the packaging development process. **Transport and Sustainability**, 6, 137–163. (2014). https://doi.org/10.1108/S2044-994120140000006006

MOURA & BANZATO. Embalagem, unitização e conteinerização. 2. ed. São Paulo: IMAM, 1997.

MUNIZ, E. C. L.; POSSAMAI, O. Complexidade de novos produtos: um modelo dinâmico para análise da perda de produtividade em sistemas produtivos. **Gestão & Produção**, v. 26, n. 1, 2019.

PALSSON, H., FINNSGARD, C., & WANSTROM, C. Selection of packaging systems in supply chains from a sustainability perspective: The case of volvo. **Packaging Technology and Science**, 26(5), 289–310. (2013). https://doi.org/10.1002/pts.1979

PETLJAK, K.; NALETINA, D.; BILOGREVIĆ, K. Considering ecologically sustainable packaging during decision-making while buying food products. **Ekonomika poljoprivrede**, v. 66, n. 1, p. 107–126, 2019.

ROBERTSON, K., GARNHAM, M., & SYMES, W. Life cycle carbon footprint of the packaging and transport of New Zealand kiwifruit. **International Journal of Life Cycle Assessment**, 19 (10), 1693–1704, 2014. https://doi.org/10.1007/s11367-014-0775-5

SASTRE, R., DE PAULA, I. C., ECHEVESTE, M. E. S., & ZENI, C. F. Radar da embalagem: uma referência preliminar para o projeto de embalagem em um contexto sistêmico e de complexidade. 12o Congresso Brasileiro de Inovação e Gestão de Desenvolvimento Do Produto, 1–16, 2019.

SASTRE, R. M.; DE PAULA, I. C.; ECHEVESTE, M. E. S. A Systematic Literature Review on Packaging Sustainability: Contents, Opportunities, and Guidelines. **Sustainability**, v. 14, n. 11, p. 6727, 2022.

SELVIARIDIS, K.; MATOPOULOS, A.; SZAMOSI, L.; PSYCHOGIOS, A. Reverse resource exchanges in service supply chains: the case of returnable transport packaging. **An International Journal**, v. 21, n. 3, p. 1–25, 2016.

SHINGO, Shigeo. A study of the Toyota Production System from an industrial engineering viewpoint. Cambridge, MA: Productivity Press, 1989.

SZCZEPAŃSKA, N.; KUDŁAK, B.; NAMIEŚNIK, J. Recent advances in assessing xenobiotics migrating from packaging material – A review. **Analytica Chimica Acta**, v. 1023, p. 1–21, 2018.

AUTHORS

ORCID: -
CRISTIANE FERRARI ZENI | Mestre em Engenharia de Produção | Programa de pós graduação em Engenharia de Produção - Universidade Federal do Rio Grande do Sul - Porto Alegre - RS - Brasil | Endereço: Rua Joao Telles, 524 sala 708 - Bom Fim - Porto Alegre - RS - CEP: 90035-120 E-mail: ferrarizeni@gmail.com

ORCID: 0000-0002-1169-3231
RICARDO MARQUES SASTRE | Doutor em Engenharia de Produção | Pós graduação em Design - Universidade Federal do Paraná - Curitiba - Paraná - PR - Brasil | Endereço: Rua Duque de Caxias, 514 - apto 302 - Centro

Histórico - Porto Alegre - RS - CEP: 90010-280
e-mail: ricsastre@gmail.com

ORCID: 0000-0003-2241-6835
ISTEFANI CARISIO DE PAULA | Doutora em Engenharia de Produção | Programa de pós graduação em Engenharia de Produção - Universidade Federal do Rio Grande do Sul - Porto Alegre - RS - Brasil | Endereço: Avenida Osvaldo Aranha, 99 - 5 andar - Bom Fim - Porto Alegre - RS - CEP: 90035-190 | E-mail: ferrarizeni@gmail.com

ORCID: 0000-0002-8645-6919
AGUINALDO DOS SANTOS | Doutor em Gestão da Produção | Pós graduação em Design - Universidade Federal do Paraná - Curitiba - Paraná - PR - Brasil | Endereço: Rua General Carneiro, 460 - Centro - Curitiba - PR - CEP: 80060-150| E-mail: asantos@ufpr.br

HOW TO CITE THIS ARTICLE

ZENI, Cristiane Ferrari. SASTRE, Ricardo Marques; PAULA, Istefani Carisio de; SANTOS, Aguinaldo dos. MIX Sustentável, v. 10, n. 2, p. 197-209, 2024. ISSN 2447-3073. Disponível em: <http://www.nexos.ufsc.br/index.php/mixsustentavel>. Acesso em: _/_/_.doi: <https://doi.org/10.29183/2447-3073.MIX2023.v10.n2.197-209>.

SUBMITTED ON: 29/05/2024
ACEPTED ON: 30/05/2024
PUBLISHED ON: 18/06/2024
RESPONSIBLE EDITORS: Lisiane Ilha Librelotto e Paulo Cesar Machado Ferroli

Record of authorship contribution:
CRediT Taxonomy (http://credit.niso.org/)

CFZ: conceptualization, formal analysis, research, methodology, project management, visualization, writing - original draft, writing - revision & editing.

RMS: conceptualization, formal analysis, research, methodology, project management, writing - revision & editing.

ICP: conceptualization, formal analysis, research, methodology, project management, writing - revision & editing.

AS: conceptualization, formal analysis, research, methodology, project management, writing - revision & editing.

Conflict declaration: nothing has been declared.