Otimização de Materiais de Embalagem em E-commerce

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Abstract

E-commerce has become a popular way for customers to make purchases. In this way, Leroy Merlin (LM), a business in the do-it-yourself (DIY) sector, has invested in the development of its online component. However, it has encountered a number of issues, including poor customer feedback regarding orders' packaging. Therefore, LM is looking to study new strategies to improve online orders' packaging costs and environmental impacts. Thus, this work aims to develop, firstly, a standardization of packaging processes, which are currently carried out on an individual basis by operators. Given the lack of data regarding the current allocation of products to packaging, there was a need to make observations in Leroy Merlin's online warehouse, located at Porto Alto. Next, several scenarios were proposed in which different packaging materials – either single-use or reusable, and different strategies are combined. Four scenarios are proposed, and with the implementation of a packaging standardization, analyses in materials consumption, packaging costs and environmental impacts, by performing a life cycle assessment (LCA), are carried out. The standardization reduced materials consumption at least in 76% for scenarios with manual packaging. A mixed option, including single-use and reusable packaging, is the most beneficial for environment, reducing its impacts in 83% when compared with the baseline. An automated option is the cheapest one, reducing costs in 65%. Contrary to what was analysed in most of the literature, reusable options are not the most beneficial in these dimensions. However, with higher return rates and reuse cycles, a reusable option becomes more attractive. .

Keywords: Circular Economy, E-commerce, Life Cycle Assessment, Packaging Materials, Primary Packaging, Standardization.

1 Introduction

The number of consumers who shop online in the European Union (EU) increased from 55% in 2012 to 75% in 2022 (Eurostat, 2023). This required businesses that previously sold their goods primarily through physical stores to give their customers the option of shopping online.

Leroy Merlin (LM) is a DIY company and already has a website where its products were sold, but due to the COVID-19 pandemic, the website usage was increased, and LM was not prepared to provide the same level of customer service when selling its products in a physical store. So, there were a number of issues while selling products online, one of which is the products' packaging. According to *Associação Portuguesa do Ambiente* (APA) (2023), packaging materials like plastic and paper are only recycled to a certain extent in Portugal (34% and 66%, respectively), which is a problematic when considering that these packages are currently only used once.

Regarding the online packaging, LM had received negative reviews from customers. Overpackaging is a significant issue in packaging operations, and consumers are becoming more concerned with the environmental impacts of packaging. Since one of the key objectives of LM is customer satisfaction, there was a need to optimize its packaging, looking at packages' material composition and the most efficient way to allocate packages to products, while reducing packaging costs, materials consumptions, and environmental impacts.

2 Case Study Description

2.1 Online Deliveries

In Leroy Merlin Portugal (LMPT), e-commerce deliveries can be either home delivery or pick up in store.

To comprehend LMPT's online operations, two aspects must be considered: (i) the delivery location, which determines whether the order will be shipped to the customer's residence or if the customer will collect it at a designated store via the pick-up in store option; (ii) the availability of inventory in each of the warehouses (Portuguese and Spanish).

When an online order is placed, firstly the software looks for each line of the order to see if each stock keeping unit (SKU) is available in one of the warehouses that serve online orders. If yes, the next step is to look at the composition of the order, i.e., how many different SKUs does the order placed have. Either it has one or more, it is necessary to evaluate if the Spanish warehouse is needed. This warehouse is only used if SKUs are not available at Portuguese warehouses, since it is more distant, implying higher costs and deliveries' lead times. However, if the Spanish warehouse is used, and the order includes more than one different SKU, the order is delivered two times (double delivery). Firstly, the items from Portuguese warehouses are shipped. Later the same happens for items from the Spanish warehouse. If the Spanish warehouse is not used, all items are delivered at once.

On the other hand, if the software retrieves that not all SKUs are available at any of the warehouses, it is looked at the proximity store of the customer. If the proximity store has all the references on stock of the placed order, the order is either delivered to the customers address or it can be picked up at store. If there are references missing in the proximity store's stock, the ones that the store has are send to the regional platform responsible for the proximity store together with the remaining references, directly ordered to the suppliers. There, the order is consolidated and delivered.

2.2 Online Packaging

LMPT is a human centric company, so one of the company's focuses is the customer satisfaction. To evaluate it, the Net promoter score (NPS) index is used, which range from -100 to 100 points, being values over 75 considered good (Reichheld, 2003). Packaging is a problem in LMPT since it has a NPS of -12.

In the current packaging operations, each operator packages a product in a different manner, leading to inefficient and inadequate packaging resulting in overpackaging. Normally, for small dimension and light products, envelopes are used. For larger SKUs, stretch film is used and then sealed with an adhesive tape. If an order is composed by two or more SKUs, generally it is used a box and the adhesive tape to seal it.

To accommodate products, LMPT uses boxes, envelopes, stretch film, corrugated cardboard, bubble wrap and filling paper, according to each product characteristics. The packages should also obey to the "decree No.152-D/2017" where it is established at "article 23 No. 17", that until 2030, 30% of the packages used must be reusable, regardless of the material they are made of.

So, the main objective in this work will be to standardize the packaging operations and evaluate the best materials to use in each group of products to increase the customer satisfaction, reduce packaging materials consumptions and environmental impacts, as well as minimizing the weight of each package to decrease packaging costs for home-delivery orders.

3 Literature Review

3.1 B2C E-commerce

Zwass (1996) introduces the terms business-to-business (B2B), when a transaction is conducted between organizations, and business-to-consumer e-commerce (B2C) when it is conducted between organizations and consumers.

In comparison to the offline market, B2C e-commerce presents unique challenges due to the increased complexity of logistics activities. The efficient management of logistics plays a crucial role in the success of B2C e-commerce, as it enables cost reduction by establishing effective connections between warehouses and customers (Mangiaracina et al., 2019).

Herhausen et al. (2015) recommend the integration of online and offline channels (omnichannel), noting that such integration enhances perceived service quality and, consequently, improves internet outcomes.

3.2. Circular Economy

Geissdoerfer et al. (2017) define circular economy (CE) "as a regenerative system in which resource input and waste, emission, and energy leakage are minimised by slowing, closing, and narrowing material and energy loops. This can be achieved through long-lasting design, maintenance, repair, reuse, remanufacturing, refurbishing, and recycling".

Mura et al. (2020) identify three key features of CE: (1) the capability of auto-regeneration through eco-innovations, preserving raw materials; (2) the maximization of product life cycles; and (3) the transition to new consumer habits.

LCA is widely recognized as a valuable methodology for evaluating the environmental impacts associated with the entire life cycle of a product (Kan & Miller, 2022). The LCA methodology is covered by International Organization for Standardization (ISO) standards 14040:2006 and 14044:2006, which provide guidelines for conducting a LCA and address the environmental aspects and potential impacts using a life-cycle approach (ISO, 2006).The LCA typically consists of four main steps: (1) scope and goal definition, (2) life cycle inventory (LCI), (3) life cycle impact assessment (LCIA), and (4) result analysis.

Holdway et al. (2010) highlights two limitations in LCA usage. Firstly, it may not be suitable for accurate assessments during the early stages of product. Secondly, it can be resource-intensive in terms of time and cost.

3.3. Packaging

Packaging material selection plays a crucial role in improving the sustainability of packaging (Peças et al., 2013). Among the various packaging materials, paperboard stands out as the most widely used material globally, being followed by flexible packaging materials and rigid plastics, ranked as the second and third most consumed packaging materials respectively (Statista, 2022).

Paper and Cardboard

Paper and cardboard are cellulose based materials, made out of lower grade wood fiber which usually includes recycled paper, and cardboard waste (Sevigné-Itoiz et al., 2015). Cellulose is safe for the environment being considered a renewable and sustainable raw material. The impact of paper recycling on greenhouse gas (GHG) emissions, specifically in terms of carbon dioxide equivalent (t CO_2 eq.), has been examined in the study conducted by Merrild et al. (2009). Their findings demonstrate that substantial GHG savings can be achieved by expanding the system range in paper recycling.

Plastics

The plastic industry relies on various polymers, including polyvinylchloride (PVC), polyethylene terephthalate (PET), polypropylene (PP), polyethylene (PE), and polyamide (PA), due to their favourable mechanical and physical characteristics (Luzi et al., 2019). Flexible packaging, on the other hand, is composed of blends or layers of different thin materials such as low-density polyethylene (LDPE), PE, or PP (Bening et al., 2021; Garofalo et al., 2018).

Tamburini et al. (2021) conducted a LCA analysis comparing PET, bioplastic, and refillable aluminium water bottles. They concluded that refillable bottles were advantageous due to their reusability. Among the plastic bottles, PET bottles had a lower environmental impact compared to bioplastic bottles.

Packaging Strategies

Packaging considers three interconnected hierarchical levels: (1) Primary package denotes the immediate interface between the packaging and the product, primarily handled by end-users; (2) secondary package (typically in the form of boxes), which facilitates handling within retail settings and represents the package exhibited in stores; (3) tertiary package, which can be employed to amalgamate numerous primary or secondary packages, enabling enhanced transportation efficiency (Pålsson et al., 2013).

One popular and widely adopted approach in the field of packaging is the 4Rs strategy, initially proposed by Klooster (2002). The 4Rs stand for recycle, reuse, renew, and rethink, encompassing key principles for sustainable packaging practices. A significant proportion of research and studies conducted on packaging strategies align with one or more of these categories. Escursell et al. (2021) provide a comprehensive overview of the prevailing challenges within the current packaging paradigm, highlighting three primary issues: overpackaging, utilization of non-renewable materials, and distribution of packages. Lu et al. (2020) argue that overpackaging often occurs as a means to enhance product protection and mitigate the risk of receiving negative consumer reviews.

Coelho et al. (2020) propose reusable packaging as a potential solution for reducing environmental impacts, with a specific focus on minimizing the packaging material per unit of packed volume. However, Accorsi et al. (2020) highlight that implementing reusable packaging involves more complex operations compared to disposable packaging.

4 Methodology

4.1 Framework and Observations

The methodology adopted is centred on economic and environmental criteria. To facilitate the comprehension of the distinct analyses undertaken, boundaries were delineated. Regarding the environmental analysis, it is considered the life cycle of each package from the extraction of raw materials until its end of life. This allows to execute a comprehensive LCA to the packaging materials. For the packaging consumption and costs, only elements that are in LMPT's control are considered, i.e., from the moment that the packages are bought from the supplier, until they are delivered to the customer.

Given the lack of information on how packaging was allocated to each type of product and the need to define the baseline, observations had to be made to comprehend how each product was packaged. The observations were conducted at the Porto Alto's warehouse between 20th June and 30th June of 2023 (from Tuesday to Friday, for two weeks).

4.2 Scenarios Definition

Packaging Selection

Currently, two types of envelopes are used in LMPT's online packaging operations. One serves for product transportation, while the other contains essential shipping information. Both types of envelopes are retained for scenarios with manual packaging. The first type is preserved because the majority of products can be accommodated within envelopes, particularly since most of the items shipped are of small volume (fit inside an envelope). The second type contains the order's shipping information. For the reusable envelopes, the RePack option was considered, as discussed by Escursell et al. (2021). According to their research, these envelopes have the potential to reduce waste and CO_2 emissions by up to 80% and can be used from 20 to 40 times. For the use of disposable envelopes, it was decided to use the *Noissue* compostable envelopes as they can be compostable between 90 and 180 days.

The shipping envelopes were maintained in all scenarios, as the envelope must have a visible part so that the order information can be viewed by the operators. However, shipment envelopes were not considered in the analysis since the quantities are the same for all the scenarios.

In the current packaging configuration, cardboard boxes of two different dimensions are used, which are discarded after its usage. To align with EU regulations, an alternative in the form of reusable boxes made from recycled PP, provided by Hipli, was explored. Single-use cardboard boxes were retained mainly due cost considerations, as they are the most economically viable option.

Efforts were directed toward standardizing external packaging materials, with a focus on achieving a consistency in the packaging process. Reusable alternatives were not explored, as the available market options predominantly serve the purpose of tertiary packaging. As such, the materials to be standardized encompass stretch film, corrugated cardboard, and bubble wrap. Consequently, the selection of paper-based materials, specifically kraft paper and kraft bubble paper, was made, with sourcing from RajaPack.

Baseline Scenarios Description:

Baseline pretends to replicate LMPT current packaging operations, maintaining all the original packaging, considering the observation results. There is no packaging standardization, opposingly to what happens in the scenarios proposed.

Scenario 1 maintains all packages as disposable, making it the seemingly simplest option to implement, involving changes primarily in packages' materials nature.

Scenario 2 features reusable boxes and envelopes, a choice favoured by the majority of studies analysed due to its positive environmental and economic implications.

Scenario 3 represents a mixed approach, including single-use envelopes and reusable boxes. This scenario aligns with the objective of incorporating 30% reusable packaging set by EU, aiming to meet minimum sustainability targets.

Scenario 4 introduces process automation through computer vision, optimizing packaging space when packing products, making it fit-to-pack. In this scenario, only single-use packaging is considered.

External packaging materials are uniform across scenarios 1, 2, and 3. Scenario 4, however, does not incorporate external packaging.

A summary of the packaging scenarios is shown in **Figure 1.**

4.3 Materials Consumption and Packaging Costs

Due to a lack of data on the weight of the materials used in the packaging processes, there was a need to compute the weight of the packages conditioning in a uniform manner.

For each order it was registered the section of each product, their respective quantities, and if there was at least one product with primary packaging. Thus, the total volume, area, and weight of an order were computed. To standardize the calculation form, it was assumed that all products were prisms.

To determine whether the packages were being used efficiently, the filling rate of each package was computed by dividing the order volume to the package capacity. For external packaging, the value was considered to be 100%.

To compute the amount of filler in each package, it was assumed that the filler would fill the area not occupied by products, but only where the filler was used, i.e., using a box does not imply the use of filling paper, but its use does imply the existence of a box.

It was considered that both corrugated cardboard and stretch film enveloped the product's area twice. This conclusion was derived from observations made during the packaging process at the Porto Alto warehouse. To estimate the surface area of each product, a uniformizing measure was adopted, assuming all products to be prisms, thus streamlining and simplifying calculations.

For packaging costs, in the case of single-use packaging, only the cost of purchasing the package from the supplier was considered, which was then multiplied by the quantity required. For reusable packaging, it was also taken in consideration the return rates and reuse cycles of a package, 32% and 20 cycles respectively.

For the automatised process, the investment was considered to be already paid to allow a fair comparison between scenarios.

The green dot value was included in all scenarios, which is a tax according to the weight of each material used.

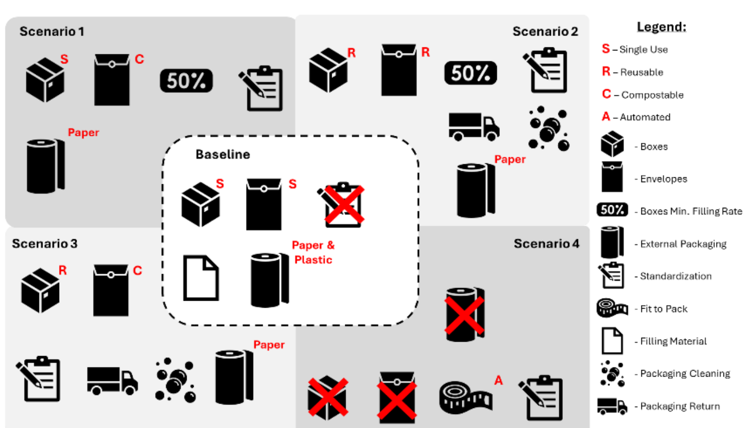

Figure 1. Packaging scenarios summary.

4.4 Life Cycle Assessment

Goal and Scope:

The LCA was performed according to ISO14040, and ISO14044 guidelines (ISO, 2006) and it is composed by four main steps: Goal and scope definition, inventory analysis, impact assessment and results interpretation. It was conducted with SimaPro 9.1 software and using the Ecoinvent v3.3 database.

The goal of this assessment is to evaluate and compare the yearly impacts of the different cradle to cradle packages, for reusable packaging, and cradle to grave packages, for single use packaging, used in the current operations configuration and in the scenarios proposed. The functional unit used is "the number of packages usages cycles in one year".

Life Cycle Inventory:

The second step of the LCA consists in the collection of the inventory associated with the baseline configuration and each scenario analysed (e.g., kilograms of CO_2 emitted). To determine this inventory, the baseline configuration and each scenario was modelled in SimaPro using references from the Ecoinvent v3.3 database.

Life Cycle Impact Assessment:

The LCIA is the third step of the LCA. This step consists of converting the inventory collected in the previous step into environmental impacts using a LCIA method. In this dissertation, the LCIA method chosen for the comparison between scenarios is ReCiPe, since it is representative for a global scale and "provides a state-of-the-art method to convert life cycle inventories to a limited number of life cycle impact scores on midpoint and endpoint level" (Huijbregts et al., 2017). For all the scenarios it was considered the ReCiPe Midpoint model to obtain the impact categories and the ReCiPe Endpoint model to obtain the Single Scores for all the scenarios and baseline. The cultural perspective used was the Hierarchist, since it is the one that seeks conscientious, considering a 100-year timeframe (Goedkoop et al., 2013).

Interpretation:

The final step of the LCA is the results interpretation. This step consists of interpreting the results of the analysis considering the goal defined in the first step of the LCA. In this step the objective is to compare the results obtained between the scenarios proposed and the current configuration.

5 Results

In this section the results from Porto Alto observations are presented. A packaging standardization is proposed and the objectives' results for the baseline and scenarios are compared. Sensitivity analyses in reuse cycles and return rates are performed.

5.1. Observations Results

A total of 242 orders were observed from the observations made at Porto Alto warehouse. However, eight of them were not considered since there were no information on its composition at the moment that the database with the orders was consulted. So, all the analysis and results obtained were based on 234 orders encompassing a total of 499 products and 298 SKUs. In the observed orders 67% have at least one product with primary packaging, and 47% have a volume lower than 5dm^3.

5.2 Packaging Standardization

Considering the observations made at the Porto Alto Warehouse, it was noticeable the lack of standardization of processes regarding the packaging of small volumes. With its implementation, greater efficiency is sought in the use of packaging, i.e., a reduction in the materials consumed and the use of larger packaging than is actually necessary. It should also be considered that this standardization was used equally for the manual scenarios presented (Scenario 1, 2 and 3), in order to allow a fair comparison in the allocation of products. The flowchart in **Figure 2** intendeds to illustrate how the process unfolds.

The allocation of packages obtained with standardization is presented in **Table 1**.

Table 1. Packaging Allocation.

Package	B	S1	S2	S3	S4
Envelopes	62	59	125	59	-
Boxes	73	2	0	4	160
External Packaging (EP)	45	74	35	72	-
Filling Paper (FP)	72	-	-	-	-

5.3 Baseline Results

Packaging Consumptions:

Considering the results obtained at **Table 2**, the predominant weight contributions come from either boxes or filling paper.

Table 2. Baseline Packaging Consumption.

Package	Consumption	%
Boxes	13 268 g	60.80%
Envelopes	1 353 g	6.20%
FP	5 826 g	26.70%
EP	1 374 g	6.30%

The substantial contribution of filling paper to the overall weight suggests that the current allocation of packages lacks efficiency. With an optimized allocation, this value could potentially be reduced, or even eliminated entirely, especially when fragile products are not considered, given that the main objective of filling paper is to protect the product. Furthermore, all packaging materials related to boxes (boxes and filling paper) account for 87.5% of the total material consumption, while envelopes have a comparatively lower impact on material usage.

Packaging Costs:

Considering packaging costs obtained in **Table 3**, boxes are the option with a higher contribution, which is expected since are the ones that also consume the most materials.

Table 3. Baseline Packaging Costs.

Package	Costs (€)	%
Boxes	26.57 €	35.03 %
Envelopes	17.54 €	23.12 %
FP	23.47 €	30.94 %
EP	5.91 €	7.80 %
Green Dot Value (GDV)	2.36 €	3.11 %

Envelopes result in 23.12% of cost contributions, which is significantly higher when compared with this package material consumptions. This is an indicative that envelopes end up has being more costly per kg than boxes despite envelopes unitary prices are cheaper.

The costs of the filling paper show that with a packaging standardization, in the current configuration, the packaging costs could be reduced in 30.94%, since filling paper would not be needed. The green dot value ends up has having a low contribution for total costs.

Packaging Environmental Impacts:

Table 4 illustrates that boxes are the packaging option with the highest contribution to environmental impacts, followed by filling materials.

Table 4. Baseline Packages' Single Score Contribution.

Package	Single Score (SS)	%
Boxes	50.06	71.16 %
Envelopes	3.34	4.75 %
FP	13.34	19.25 %
EP	3.41	4.84 %

This aligns with the reasoning discussed regarding the materials consumption, being the total single score largely attributed to the substantial material consumption associated with boxes. However, while boxes consume approximately twice the weight of filling material, this proportion does not directly translate to environmental impacts. In fact, boxes are 3.7 times more environmentally impactful than filling paper. This disparity underlines that the environmental impact is not solely determined by material weight but also depends on other factors such as production processes, energy usage, and transportation.

5.4 Scenarios results and comparation with Baseline

Packages Filling Rate:

Table 5 presents the average filling rates in each scenario.

Table 5. Scenarios Average Filling Rate.

Scenario	Average Filling Rate
Baseline (B)	55.05%
Scenario 1 (S1)	65.90%
Scenario 2 (S2)	32.20%
Scenario 3 (S3)	64.66%
Scenario 4 (S4)	100.00%

In scenarios 1 and 3 the values are higher when compared with the baseline configuration. This indicates that the standardization allows to improve the packaging efficiency, increasing the

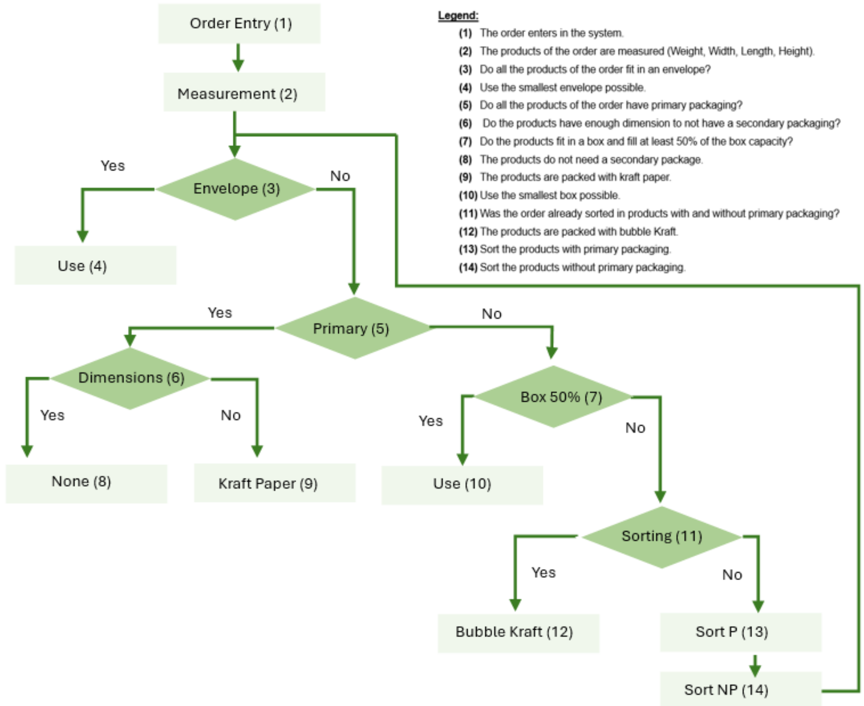

Figure 2. Packaging Standardization Flowchart.

filling rates in 10 percentual points for these scenarios.

Scenario 2 presents the lowest values, so it is an indicator that, despite having packaging standardization, the reusable packages are excessively large for the products packed.

For scenario 4, since the orders were fit-to-pack, it was considered that the filling rate of the orders was 100%.

A higher filling rate would mean a better efficiency in packaging allocation, being expected that the materials consumption would be lower.

Packaging Consumptions:

From **Table 6**, it can be concluded that the packaging consumptions contribution in scenarios 1 and 3 are similar, being the small differences due to boxes' allocation.

Table 6. Scenarios Packaging Consumptions.

Package	S1	S2	S3	S4
Boxes	896 g	0 g	142 g	20 771 g
Envelopes	545 g	2 056 g	545 g	0 g
FP	0 g	0 g	0 g	0 g
EP	3 691 g	3 160 g	3 709 g	124 g

In both scenarios, the majority of packages consumption is related with the external packaging (over 60%), being bubble kraft the most used option. This means that a high percentage of products that do not have primary packaging, did not match the criteria on the standardization process, so it was necessary to use this packaging option.

In Scenario 2, external package is the most consumed, despite envelopes being the most used package. This is expected due to the reusable nature of the envelopes in this scenario, so more packaging usages do not necessarily mean higher consumptions. The consumption of materials will be reflected in packaging costs.

Scenario 4 consumption is only composed by cardboard and kraft tape, being the first responsible for 99% of the total consumptions while kraft tape is only used to seal up the boxes.

Packaging Costs:

Considering the packaging costs presented in **Table 7** in scenarios 1 and 3, external packaging corresponds to 63% and 62% of total costs respectively. This goes in line with what was observed for materials consumption.

Table 7. Scenarios Packaging Costs.

Package	S1	S2	S3	S4
Boxes	0.81 €	0 €	2.28 €	21.24 €
Envelopes	23.80 €	63.43 €	23.80 €	0.00 €
EP	43.44 €	37.41 €	43.58 €	2.75 €
GDV	0.55 €	0.34 €	0.31€	2.23 €

For the scenario 2, envelopes correspond to 63% of packaging costs. Despite not being the most consumed package, the total cost values are higher since the unitary cost of a reusable envelope, on average, is about 13 times more expensive than the current envelopes. But considering the reusable and return rates, this value is softened, since the value is amortized for each usage. However, the reuse and return rates are still not enough to make scenario 2 the cheapest option. Instead, Scenario 4 is the one with lower costs, despite being the one with higher material consumption.

Environmental Impacts:

Regarding the single scores presented in **Figure 3,** all the scenarios, when compared with the baseline option, produce better results. The single scores follow the tendency that: the more total packaging consumed, the larger the single is.

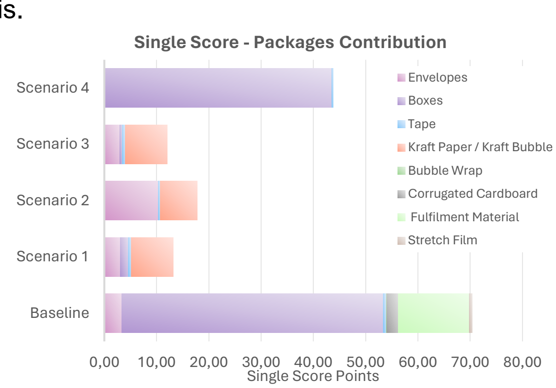

Figure 3. Single Score across scenarios.

In scenario 1 , boxes represent only 17.5% of the materials consumption, while impacting 11% of the total single score. This means that, in scenario 1, boxes are used more efficiently. A lesser quantity does not impact as much in proportion. However, in this scenario, envelopes perform poorly, representing 23% of total single score while consuming 10% of the materials.

The same happens for scenario 2, where envelopes corresponded only to 39% of packaging consumption but 58% to the single score. This is related with the cleaning process, which was included in the impacts of reusable envelopes, helping to explain such a big disparity in values.

Scenario 3 has the lowest Single Score. Despite having more boxes used when compared to scenario 1, since they are reusable, the materials consumption ends up being lower.

5.5. Sensitivity Analysis

Several sensitivity analyses on packages return rates and reuse cycles were made.

The return rates and reuse cycles were changed in order to understand how reusable packages would behave with higher values (**Table 8**). Only scenarios 2 and 3 were considered since are the ones that use reusable packages. As expected, the variations in scenario 2 in all criteria are higher. This happens since the number of reusable packages used in this scenario are higher than the ones used in scenario 3. An increase in return rates benefits scenario 2, making it an option with lower packaging costs than scenario 3 for return rates over 65%. Considering packaging consumption, for return rates over 56%, scenario 2 consumes less packaging. An increase in return rates leads to a decrease in the single score, going in line with the tendency found for the reduction in materials consumption. For return rates over 57%, scenario 2 has lower values than scenario 1, regarding the single score.

Reuse cycles were only tested until 40 cycles since that were the maximum value indicated by RePack. The variation of reuse cycles has similar effects: Scenario 2 consumes less than scenario 3 from 34.7 and for costs and environmental impacts has similar values at 40 reuse cycles.

6 Conclusions and Future Research

E-commerce has been a growing sales method, so there was a need to address its new challenges, concerning costs and environmental impacts. Product packaging has always been connected with the delivery of orders. Therefore, it was a challenge for LMPT's online operations to optimize its packaging operations. A focus was made in home-delivery where product packaging

Table 8. Variation in Reuse Cycles and Return Rates values.

	Scenario	Reuse Cycles 10	20*	30	40	Return Rates 32%*	40%	50%	60%	70%
S2	Costs (€)	164.61	101.18	80.03	69.46	101.18	88.49	78.34	71.58	66.74
	Consumptions (g)	7 272	5 216	4 531	4 188	5 216	4 805	4 476	4 257	4 100
	SS (pt)	28.06	17.18	14.32	12.29	17.18	15.69	14.05	12.97	12.17
S3	Costs (€)	72.04	69.76	69.00	68.62	69.76	69.30	68.94	68.69	68.52
	Consumptions (g)	4 537	4 396	4 348	4 325	4 396	4 369	4 345	4 329	4 319
	SS (pt)	12.57	12.07	11.87	11.78	12.07	11.97	11.88	11.83	11.80

*The values highlighted correspond to the ones used in the scenarios'

is fundamental in the majority of orders.

In the first objective, packaging costs, scenario 2 is the one who has the most costs. Since this could be explained to low return rates and reuse cycles, a sensitivity analysis was conducted in these parameters. It was observed that, by increasing both values, scenario 2 could have more competitive costs but would never be the option with lower costs.

The second objective was to reduce materials consumption. By shifting the usage of boxes, to external packaging, this reduction was observed. The main differences in each scenario lay in the individual weights of the used envelopes and boxes (reusable, compostable or disposable). Regarding this objective, scenario 3 was the one with lower materials consumed.

The third objective was to reduce environmental impacts of the packaging process. By looking at the single scores, scenario 3 was the one with the lowest value, while the scenario 4 was the one with the highest considering the scenarios proposed.

For future work, it would be interesting to implement this standardization process and made possible adjustments accordingly with operators and clients' feedback. Thus, this standardization process should be extended to pick up in store online orders. Costs regarding the transportation of reusable packages to the warehouses, its cleaning, and a caution value to return the packages should be studied and added into reusable costs accountability.

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