An investigation into the issue of overpackaging - examining the case of paper packaging

Abstract

Packaging and more specifically environmentally friendly packaging has received considerable attention over the years. Various solutions have been presented by researchers and practitioners regarding environmentally friendly packaging, where this research tackles this issue from a packaging design point of view. This paper seeks to provide an investigation into the issue of overpackaging regarding the outer paper packaging box and the various implications coming from the use of overpackaging in a company's operations, while investigating and discussing its importance for the environment, the industry and the community.

A practical case study has been analyzed in which two paper packaging design options of the same corrugated box are investigated in terms of: paper quality and final packaging cost. The case study is followed by a detailed comparison between two selected options, in order to show the strengths and weaknesses involved in each case. The analysis provides evidence that any improvements in packaging design may result into weight and transportation benefits and at the same time affect the environment in a positive way by reducing the raw materials needed and thus the total weight of the final packaged product.

The results provide significant evidence that a thorough investigation of the overpackaging issue, has the potential to bring economic benefits to a company where the protection of the product carried is ensured, the logistics activities are facilitated, the informative role of packaging is to the required standard and the cost is maintained low.

The paper contributes by providing an environmentally and economically sustainable solution to paper packaging companies interested in improving the outer packaging design. The paper brings theoretical consideration to the issues of overpackaging by moving forward the research agenda of economically and environmentally sustainable packaging.

Keywords: packaging, overpackaging, cost effectiveness, packaging weight, packaging evaluation, packaging effectiveness

1. Introduction

One key issue concerning the packaging sector is the excess, unnecessary raw material content build in into the packaging material, with specific reference to the outer packaging for the purpose of protecting the product carried. As cited by Qing and Guirong (2012) nowadays the environmental impacts of packaging are intense where for most products, packaging is single-used and turns into waste right after its use. In many instances, the outer packaging used considers additional material, where the link made with the product carried is not always established. This results in additional, excess packaging that may result in unnecessary waste. The goal is to create eco-friendly packaging by covering at the same time the other packaging traditional requirements (i.e. protection, marketing characteristics and logistics-related features) (Bovea, 2007).

The aim of this paper is to show how overpackaging issue can be challenged by presenting economic and environmental benefits to paper packaging manufacturers and their customers by raising the awareness on further opportunity of waste reduction. In the context of paper packaging, opportunities for waste reductions are not only at the post consumption phase (Elgaaïed-Gambier, 2016), they could also be considered at the product design phase such as redesigning the outer packaging box to avoid overpackaging. This material intends to provide the opportunity for practitioners to engage into implementing a viable solution when dealing with aspects of overpackaging when paper packaging is being used. This material not only has practical benefits, but also benefits that are of interest to researchers when analyzing the issue of overpackaging. The analysis method presented here has been implemented in practice,

still, this approach highlights the way in which the issue of overpackaging can be tackled in the context of paper packaging. Also, indicates the type of benefits that could be observed when this packaging design approach is being considered and furthers the body of academic literature in this field.

In recent years, manufacturers have considered the issues of overpackaging where efforts have been put in place to consider environmentally friendly outer packaging (Georgakoudis et al., 2018; Elgaaïed-Gambier, 2016; Dangelico and Pujari, 2010). Overpackaging elimination could further cause the product to become more appealing to environmentally conscious consumers as well as employees (Monnot et. al., 2019). Moreover, overpackaging reduction (or total elimination) could result in significant cost savings for an industrial user, since according to SEVADEC (2015) overpackaging can represent up to 65% of the total cost of the product itself.

The aspect of overpackaging has been discussed in the context of the product inside of the outer packaging. As noted by Monnot et al. (2019), the brand image and customer purchasing information may be affected by eliminating the overpackaging of a product, where to our understanding, the product is referred here as the product inside the outer packaging. Their study highlights that non-overpackaging for a particular product, only has a negative impact on purchasing decision for non-environmentally conscious consumers.

The investigation begins with a review of the literature. Initially, in Section 2.1. the concepts of excessive packaging and overpackaged products, along with the modern life's trends and habits are thoroughly described, while Section 2.2. deals with a detailed presentation of the overpackaging issue. Section 3, includes an experimental analysis of the overpackaging concept while using the outer packaging case of a paper

packaging manufacturer. At this point a case study has been explored (Section 3) in which two options of the same corrugated box are investigated in terms of: quality and cost followed by a detailed comparison between them, in order to show the strengths and weaknesses involved. However, in order to gather more data and further improve the analysis, the results from the study of four more corrugated boxes are also presented in the investigation. The benefits of this step are twofold: firstly, to make a complete analysis of all corrugated boxes of the customer and make sure that redesigning could offer significant ameliorations to a company's packaging and secondly to ensure that the case investigated was not the most extreme scenario, which could lead to erroneous conclusions.

Finally, section 4 includes the discussion and presents concluding remarks on a number of points. Suggestions for further work concerning the overpackaging issue are also given in this section.

2. Literature Review

2.1. Excessive Packaging – Modern Life - Over Packaged Products

As already mentioned in the introduction, there are situations where companies are using excessive packaging, utilizing unnecessary raw materials, where further packaging savings could be achieved (Livingstone and Sparks, 1994; Dangelico and Pujari, 2010, Chen et al., 2017). The issue of overpackaging has also been enquired by researchers (Elgaaïed-Gambier, 2016) from consumer's perception, where the angle of the argument follows the lines that non-overpacked products should not be associated with reduction in the quality of products, or marketing limitations. Chen et al., (2017) acknowledged the fact that there is no agreed definition of what constitutes excessive

packaging, however they refer to aspects such as: packaging that supplies too much weight, or is too heavy, or it too large and too costly to name just a few of the characteristics highlighted in their work.

An interesting aspect is that of Gustavo et al., (2018) who argue the concept of redesigning packaging which may result in potential economic gains. An evaluation of the outer packaging from a packaging redesign point of view, has the potential to tackle the issue of overpackaging. Sheridan (1992) and Andel (1991) debate that packaging redesign could offer significant cost advantages to a company that can be summarized to the following points:

- Lighter packaging may result in lower transportation costs.
- More protective packaging may reduce damage and requirements for special handling.
- Environmentally conscious packaging may save disposal costs and improve the company's image.

Innovations into redesigning the outer packaging with the view to results into a lighter, more environmentally friendly packaging could bring a number of benefits to the packaging manufacturer, the transport company as well as to the environmentally conscious consumers. According to Ilg (2019) green product innovations offer significant benefits to different stakeholders throughout their life cycle while strengthening efficiency and core competences. Moreover, various stakeholders tend to press firms to move towards green product innovations (Li et al., 2018). Li et al., (2019) support that there is a strong relation between innovation and industrial green development mostly low-carbon production and resource reduction. Thus, it is argued that green development could be the solution to the over-consumption of natural

resources and pollution caused by the industrial development. However, Lin et al., (2013) describe that market demand seems to be the key factor affecting green product innovation and firm performance. It is also supported that green product innovation has a strong positive correlation with firm performance. Among others, green product innovation can have a positive impact on a firm's financial performance affecting in the same way the green image of the company (Xie et al., 2019; Ar, 2012). In a similar research conducted by Chan et al., (2016) it is shown that the environmental regulations have a positive effect towards green product innovations.

However, Stucki et al., (2018) investigate the negative impact of various regulations and taxes on green product innovations. They argue that if these policies do not trigger additional demand, the industry tends to be reluctant to innovate. Thus, green policies should be designed in such a way that facilitate the industries to effectively integrate green innovation.

Nevertheless, improper or inefficient packaging can have as a result higher costs due to handling difficulties and furthermore can reduce future sales due to various damages (ex. moisture, dust, contamination, breakage), caused to the product carried in the outer packaging during transportation or handling (Coyle et al., 2003). According to Behmanesh (Iran Daily, 2006), a lot of the high quality exported Iranian agro products, are wasted due to improper or low-quality packaging. In developing countries, the use of improper packaging results in about 25-30% of packaging wastage in the supply chain (Dharmadhikari, 2012). According to Pellingra (2012) in the UK 1.2 million bananas per day are thrown away due to improper or missing packaging. On the other hand, using lighter packaging (meaning the use of less packaging materials) of lower quality doesn't help the environment either if this results in damaged products. Poulter (2010) supports that the effort of Tesco to minimize plastic usage in its bags resulted in

bags of low quality and strength. This in turn has driven customers to double – up the bags (especially for heavy products) in order to avoid potential damage to the contents. This aspect triggers the argument that lighter packaging is linked to the weight of the product it is carrying.

Global trade and different regional consumption habits emphasize the importance of packaging. The expansion of many companies to foreign markets (compared with the domestic markets where they used to trade), has increased the distances between the place of production and the point of consumption (Jahre and Hatteland, 2004), therefore products are in their outer-packaging, in transit for a longer period of time. It is therefore essential that export companies use efficient packaging for their products for minimizing any damages and ultimately avoid the issue of products being stockout when they are being required. To further emphasize the link between stockout and packaging, it is relevant to indicate that despite the fact that the penalty for being out of stock for the manufacturer or the retailer depends on many things (type of product, consumption habits etc.) and is not ever stable, stockouts can cause customers to abstain from buying or search for the product elsewhere (Zinn and Liu, 2001).

This investigation is looking to take the issue of overpackaging from the aspects of forming lighter finished packaging product that is environmentally and economically sustainable and maintaining the packaging properties regarding product protection and offering.

2.2. The Overpackaging Issue

Overpackaging has attracted the attention of practitioners, researchers and consumers, however, we are still to reach a definition of overpackaging in the academic literature.

According to the Cambridge Dictionary (2019): “overpackaged products are wrapped in more material than is needed or is wanted” while in Merriam-Webster (n.d.) dictionary it is cited that “overpackage is to use an excessive amount of packaging for something, such as a product”. Within this context, this research is looking to give further understanding to the term used as overpackaging. Packaging for a product can be in the form of primary and secondary packaging. The primary packaging forms the material that first covers the product with particular functions such as protection, providing key information regarding the product, support in transit, handling and is the material that carry out particular marketing functions. A set of units of primary packaging can be surrounded by the secondary packaging when these products are being transported and/ or stored in a warehouse. The effort of this work focuses on the overpackaging issue of the secondary packaging. This work is exploratory in nature and aims to investigate if by reducing excessive packaging material within the secondary packaging, the transportation and staking function of the secondary packaging is being affected.

According to Inns (2012), in most of the cases the reason of overpackaging is in order to avoid damage in transit (especially when poor local transport conditions occur).

A number of issues are identified with overpackaging such as overfull land fields, the use of additional energy and pollutants by the manufacturers producing these (Kuhl, 2002), higher cost associated with production and transportation, are too heavy (Chen, et al., 2017) and these issues are just to name a few.

The detailed analysis of the entire packaging (i.e. primary, secondary, tertiary) that an industrial consumer uses in its packaging operations, could reveal several weaknesses, problems or failures that, if addressed effectively, could offer multiple advantages to the user.

At this point, and for the needs of research, the factor of corrugated packaging quality was selected to be examined. Its basic elements as well as a related case study are presented below. The following figure (Figure 1) aims to describe the overpackaging issue that have been observed from the selected case company.

----------Figure 1 around here----------

Figure 1. The overpackaging issue

We usually use the term strength to refer to the compressive strength of packages. The compressive strength represents the maximum compression a material can withstand without failure (Parker, 2003). In a similar way the resistance of packaging represents the ability of packaging to withstand maximum compression when stacked. However, the contained product further affects the durability of the external packaging since its rigidity contributes to the overall resistance of the packaging to the compression strength.

In corrugated packaging, quality is strongly connected with packaging attributes such as strength and resistance as well as the ability to protect the contained product in conditions of high humidity. In this way, a high-quality packaging is in general more resistant in terms of protection when compared with a low-quality packaging. The general idea behind the overpackaging issue for what is relevant to the paper corrugated packaging is that the use of paper of heavier g/m^2 gives, in general, packaging of higher quality and higher strength and as a result of higher cost. In addition, the use of paper of heavier g/m^2 gives the packaging, stacking strength, usually is higher than needed. This fact produces the overpackaging issue that as soon as it is noticed should be faced in an effective way. This problem can be approached by changing the packaging type (shape, paper type, paper grammage) that leads to the production of lighter packaging with suitable strength that in most cases is cheaper than the replaced packaging.

In the past, according to Multi Pack, it was common practice for packaging manufacturers to produce and sell corrugated boxes of higher resistance (ie. quality), since most customers used to require single wall containers[1] of high strength that would, in some cases, be 500 – 560g/m^2. The cost however was modulated accordingly. Since the end of 1990's and the beginning of 2000's the market has begun to require low-cost packaging solutions. From that time on, the vast majority of single wall paper corrugated containers do not exceed 480g/m^2. Minor exceptions occur when corrugated boxes of heavier weight and higher strength are imperative, which is subject to the features of the product included.

The general advantages behind the redesigning idea are: lower packaging cost, lower overall transportation cost and savings for the company (see Figure 1).

3. The Case study

The case study has been selected by the researchers to evaluate the overpackaging issue for the secondary packaging. At the time when the research was conducted the paper manufacturing company had a new cooperation with a food company and decided to proceed with an analysis on possible overpackaging issues. The researcher has obtained data regarding a number of cases i.e. five different corrugated packages used by the food company as a secondary packaging solution. From these cases they have selected the following to further investigate (see Table 1). The analysis required primary data to be provided by the company on the offered packaging manufacturing cost, selling price, dimensions, order quantities, paper grammage, further technical specifications and ECT results that were carried out in the lab.

[1] Single Wall paper corrugated boxes are comprised of 3 paper layers.

The company explained to the researcher that the time when the research was conducted, there was a need for an analysis of cases that were affected by the overpackaging. Thus, the data of the cases were provided to the researcher and the analysis was ready to be conducted.

By successfully dealing with the issues as arising from the overpackaging problem, it is estimated that the company will be able to implement the proposed solution and overcome the cost issue of the specific items.

The approach taken to analyses the overpackaging issue is detailed in the sections below. Its purpose is to show that a detailed analysis of the packaging used by a company may reveal opportunities to improve packaging performance and contribute to further cost savings (e.g. storage, transportation), as well. Further indirect gains, as shown below, include a better overall environmental performance of packaging and lessened outlay to benefit the final consumer.

In the selected Case Study, the customer had been identified as using an unsuitable secondary packaging type (corrugated box) for a number of years when the company decided to change their packaging supplier. The problems originating from using excessive packaging, along with a comparative estimate of what should have been considered in the previous years by the case company is being explored. The case constructed for analysis is presented in particular conditions, however if the weight of the product inside the packaging increases, the strength of the outer packaging needs adjusting. It should be stressed that the type of paper used is another important aspect. For example, the use of paper with high elasticity and durability, such as Kraft (produced by chemical pulp), which appears to be more resistant and durable when compared with recycled papers may further affect the decisions of the company (Emblem & Emblem, 2012).

There upon, several problems had to be dealt with, some owing to the previous supplier's erroneous advice, a factor which is not to be examined here. What is going to be thoroughly

explored, are the problems originating from using improper packaging, along with a comparative estimate of what should have been done instead in previous years.

The details of the annual packaging needs of the company, are shown in Table 1.

Table 1. Annual needs per packaging code - (Source: Georgakoudis, 2014)

----------Table 1 around here----------

Code No 1 analysis: Corrugated box No 1 is going to be examined below:

From the observations conducted within the case study company, it was evident that unsuitable secondary packaging has been used over a number of years. After a detailed analysis of the situation and the individual needs of the customer, the company has decided to investigate the design of the packaging. A solution to this approach is presented below.

- Option A is what the company used to employ in its packaging operations.
- Option B is the proposed solution.

Table 2. Technical information[2] - (Source: Georgakoudis, 2014)

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The general form to estimate the sheet weight for the double-sided corrugated box, is the following (there might be differences among different machines):

[2] Flutes supply the rigidity to the board. Flutes are designed by height (thickness) and density (number per linear foot). Higher (less dense) flutes in addition to stacking strength provide softer cushion characteristics, while lower (more dense) flutes provide greater flat crush resistance, smoother print surfaces, and crisper score lines. Flutes are often used in combinations such as BC double wall, which provides an overlap of required characteristics (Foster, 2009).

----------Table 8 around here----------

----------Figure 7 around here----------

While, the general form to estimate the sheet weight for the single-sided corrugated box, is the following (there might be differences among different machines):

----------Figure 8 around here----------

where,

----------Figure 1b around here----------

As shown in Table 2, the corrugated box No1 is a double-sided container and the sheet weight is 630 g/piece. The above double-sided layer container is manufactured by using 5 different layers of paper with different grammages (A:120 g/m^2, B:127 g/m^2, C:100 g/m^2, D:127 g/m^2, E:100 g/m^2) as shown in Figure 2.

In the alternative proposed solution i.e. Option B, the previous double-sided layer corrugated box of Option A, is replaced by a single sided layer corrugated container with a sheet weight of 420 g/piece and it is manufactured by using 3 different layers of paper with different grammages (A:130 g/m^2, B:127 g/m^2, C:130 g/m^2) as shown in Figure 3.

Table 3. Cost review - (Source: Georgakoudis, 2014)

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In Option A the corrugated box is manufactured by using only recycled papers. The materials cost per sheet is 0.2613€.

Here again, in Option B the corrugated box is manufactured by using only recycled papers. The materials cost per sheet is 0.1748€.

Comparison

Table 4. Comparison - (Source: Georgakoudis, 2014)

----------Table 4 around here----------

As presented in Table 4, the estimated selling price of the corrugated packaging by the packaging manufacturer is 0.5025€/piece for Option A and 0.3297€/piece for Option B. Therefore, the user of the packaging (industrial customer) is going to pay 34.4% less money in order to acquire the replaced packaging (No 1).

In order to understand the stacking strength of each of the above Options, an Edge Crush Test was performed in the lab at 20^{o}C. The specific test is conducted in the lab and is used to appraise the approximate compression strength of the corrugated board (Kirwan, 2005). The results are presented below (see Table 5):

Table 5. ECT and strength needs - (Source: Georgakoudis, 2014)

----------Table 5 around here----------

For Option A, the Edge Crush Test (ECT) showed that the stacking strength of the packaging is ≤190kg. For Option B, the ECT showed that the stacking strength of the packaging is ≤104kg. The strength needs for the specific packaging code is ~96.4kg. The estimation of the strength needs is shown below (see Figure 4, Figure 5).

The boxes are stacked on pallets. Each pallet contains six (6) layers of boxes. Each box weighs 8kg (4x2kg). There are five (5) layers of boxes over the bottom layer. The weight on each bottom box is:

$$x = 8kg/box * 5layers$$

$$x = 40kg$$

----------Figure 4 around here----------

Figure 4. Palletizing / Most distressed layer - (Source: Georgakoudis, 2014)

At this stage, the minimum needed strength of the bottom box should be estimated. Although the company provided the researcher with all the relevant information in estimating the minimum needed strength, the researcher decided to adopt a different method based on the method taught by the Michigan State University (https://www.msu.edu/).

According to the Michigan State University, an indicative strength measure of a corrugated box requires that the packaging under investigation should be placed under a dynamic load in given experimental conditions to measure the dynamic box compression, thus deducing any potential failure.

$$BoxCompression = Load\ on\ bottom\ Box * Estimated\ Safety\ Factor^{3}$$

$$x = 40kg * 2.41$$

$$\boldsymbol{x = 96.4kg}$$

[3]The "Estimated Safety Factor" affects the Box Compression outcome. In order to calculate the Estimated Safety Factor, a number of conditions should be included such as: storage time, humidity, stacking pattern, pallet overhang and handling losses.

$$EstimatedSafetyFactor = \frac{1}{ST * RH * PP * OH * HL}$$

ST = Storage Time Effect, **RH** = Relative Humidity Effect, **PP** = Pallet Pattern Effect, **OH** = Overhang Effect, **HL** = Handling Loss Effect

According to the customer:

- The load is going to be stored for an average of 10 days.
- The relative humidity is 55%.
- The box effectiveness factor is 0.7.
- It is assumed that the handling losses are going to be no more than 5%.

$$EstimatedSafetyFactor = \frac{1}{0.65 * 0.96 * 0.7 * 1 * 0.95}$$

$$EstimatedSafetyFactor = 2.41$$

----------Figure 5 around here----------

Figure 5. Case study overview - (Source: Georgakoudis, 2014)

As it is clearly shown from the ECT test, the Option A provides much more resistance and protection than needed (i.e. ≤190 kg over ~96,4 kg). Option B, is much closer to the protection needs of the company for the specific product (i.e. ≤104 kg over ~96,4 kg). Hence, Option B is more suitable as a packaging solution, compared to Option A (if all other factors remain stable).

Based on the annual packaging needs of the company, the cost difference is formulated as follows (see Table 6):

Table 6. Cost difference between Option A and Option B - (Source: Georgakoudis, 2014)

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----------Figure 6 around here----------

Figure 6. Cost overview - (Source: Georgakoudis, 2014)

In the same manner the results for all other packaging codes were calculated and are presented in Table 7:

Table 7. Packaging results - (Source: Georgakoudis, 2014)

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Limitations: The strength needs for the examined containers were calculated based on specific conditions (time of storage=10 days, relative humidity=55%, no overhang, handling losses no more than 5%). The outcomes of the study may vary if any of these factors are changed.

1. The Case Study investigates a particular scenario but the outcomes are indicative. Still, the detailed analysis of the packaging needs of a company may reveal similar or even more significant problems.

2. In each packaging code, different paper combinations were used in order to provide the most suitable results. The different paper combinations for the production of the corrugated box may provide a different grade of protection or stacking strength and this affects the final packaging cost. Still, the above method of analysis is applicable to any case and maybe used to estimate individual costs.

4. Discussion

The above analysis shows a number of significant aspects related with the overpackaging issue. The industrial competition forces companies to constantly keep the prices of their products at an acceptable level for the consumers, thus less cost for the industrial customer results in less cost for the final consumer. As demonstrated above, lighter packaging results (in most of the cases) in cheaper packaging, which favorably supports domestic products. As already mentioned above, a wide range of factors such as the means of transport used, fatigue time, warehousing conditions, strongly influence the required stacking strength. Therefore, products imported from other countries, far from the country of destination, require stronger packaging in order to protect more effectively every single product along the supply chain. Heavier packaging in turn, means higher transportation cost, more fuel consumption, higher CO_2 emission that is ultimately added to the final selling price of the product.

On the other hand, at higher resistance needs, sometimes, the use of better-quality paper may provide with even better results avoiding the need of moving to double sided containers. If, for example, a single sided wall container weighing 480g/m^2 should be replaced for strength reasons and the packaging manufacturer provides a single sided wall container with 520g/m^2 (assuming that the strength needs are fulfilled), the cost would be far lower than to substitute with a double-sided wall container of 680g/m^2.

The same detailed packaging analysis performed above, could be extended to other types of packaging (e.g. primary packaging) as well as packaging manufactured from other materials (plastic, glass, metal etc). In addition, the full packaging analysis of a product (in case that the product includes more than one kind of packaging), may give a better understanding of the overpackaging issue and provide the industrial user with cost effective solutions.

5. Conclusion and Further Work

The above detailed analysis of one factor strongly related with the overpackaging issue i.e. quality, focused on corrugated packaging, clearly shows that the careful analysis of the packaging is very important for an industrial customer. The main conclusion of the analysis is that a better redesign of the packaging itself, may result in a lower overall packaging cost and a better environmental performance since the overpackaging issue aggravates the environment both from a raw materials and transportation perspective (fuel emissions).

It should be noted that the analysis of packaging needs should be thorough and detailed, in order to avoid any problematic situations for the industrial customer such as excessive packaging, inappropriate performance and complete or partial damages throughout the supply chain.

These problems, could result in higher costs both from direct economic losses or from indirect losses such as lost sales or replenishment delays.

The present research, could be further extended by including a similar analysis of all packaging types (primary, secondary, transport) used by a company in its industrial processes. It should be underlined that a thorough analysis of the packaging needs of the industrial user may provide the company with lower overall packaging, transportation and storage costs.

In addition, a better redesign of the corrugated packaging may drive the industrial customer to use lighter packaging for some of his products with no special needs or small time of

warehousing. On the other hand, heavier and stronger packaging should be used for products under particular circumstances, such as long-time storage, high humidity rates, or during long distance transportation and storage, as may be the case, for products exported, thus saving a great deal of money.

Dealing with the idea of overpackaging at the manufacturing stage in the supply chain promotes waste reduction earlier in the chain before the packed products arrive to retailers. This not only has environmentally and economic benefits to the manufacturer producing these packaging products, but also to all parties in the chain adopting these products.

Further research may include an investigation on how overpackaging is perceived by industrial customers. The results could contribute in improving the packaging processes facing at the same time the overpackaging issue.

Another aspect that could be further investigated is the connection of marketing with the overpackaging issue. Various efforts related with the limitation of overpackaging phenomenon should be examined in relation with the acceptance of any changes by the participants of the supply chain.

At last, it should be stressed that the present analysis could be further extended by including an investigation of other paper types as well such as KRAFT paper. The outcomes may reveal different aspects on the overpackaging issue that could be further combined with the outcomes of the present research and provide further evidence that the overpackaging issue can be successfully resolved if serious measures were taken and specific methods of analysis followed.

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Figure 1

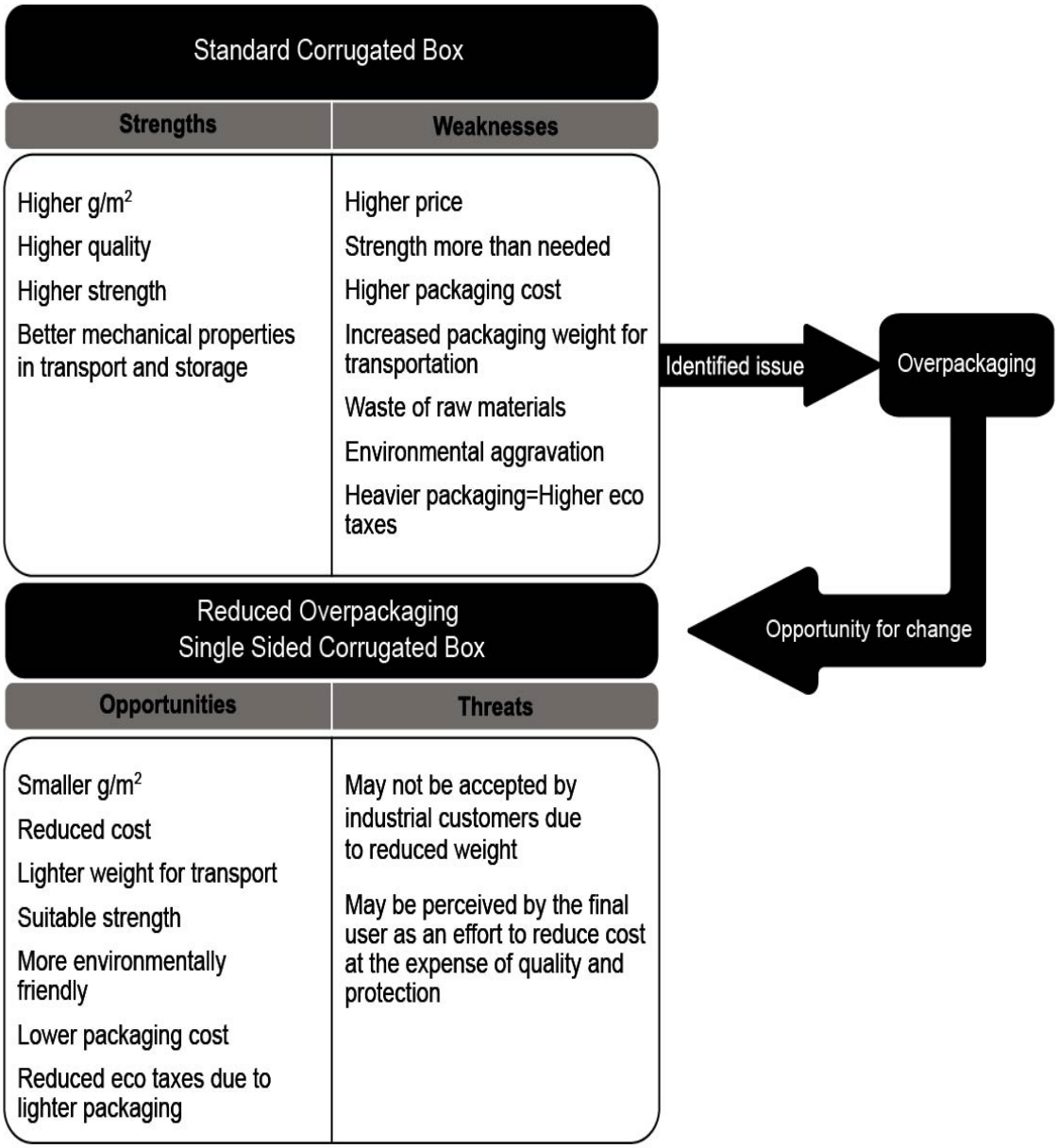
Standard Corrugated Box
Strengths
Weaknesses
Higher g/m2
Higher quality
Higher strength
Better mechanical properties in transport and storage
Higher price
Strength more than needed
Higher packaging cost
Increased packaging weight for transportation
Waste of raw materials
Environmental aggravation
Heavier packaging=Higher eco taxes
Identified issue
Overpackaging
Opportunity for change
Reduced Overpackaging
Single Sided Corrugated Box
Opportunities
Threats
Smaller g/m2
Reduced cost
Lighter weight for transport
Suitable strength
More environmentally friendly
Lower packaging cost
Reduced eco taxes due to lighter packaging
May not be accepted by industrial customers due to reduced weight
May be perceived by the final user as an effort to reduce cost at the expense of quality and protection

Figure 1b

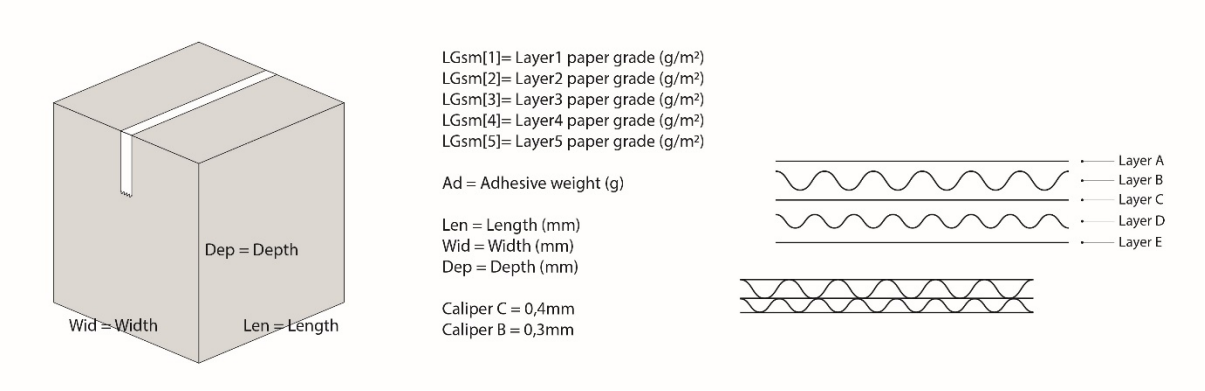

Figure 2

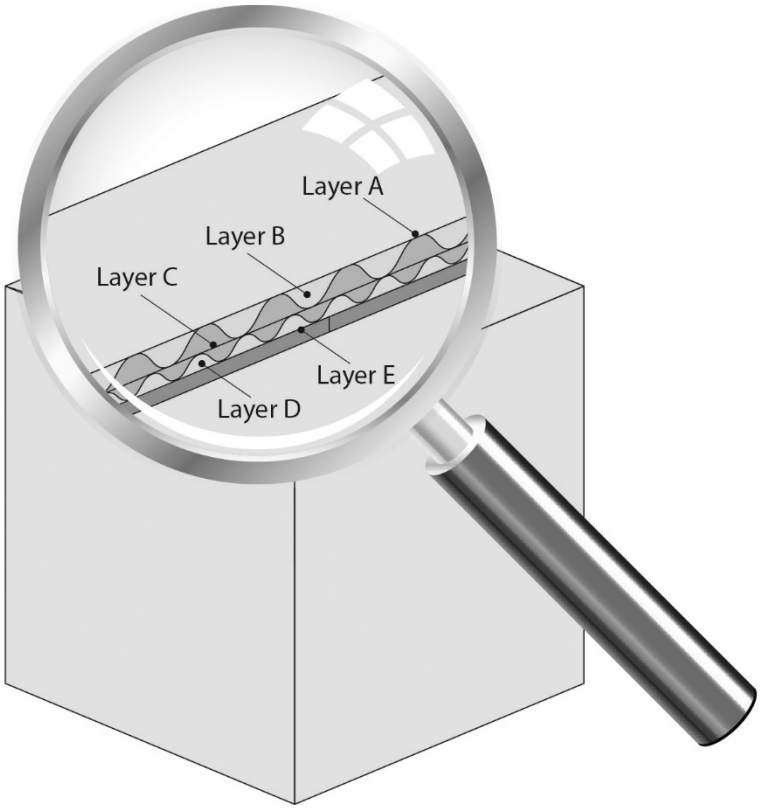

Figure 3

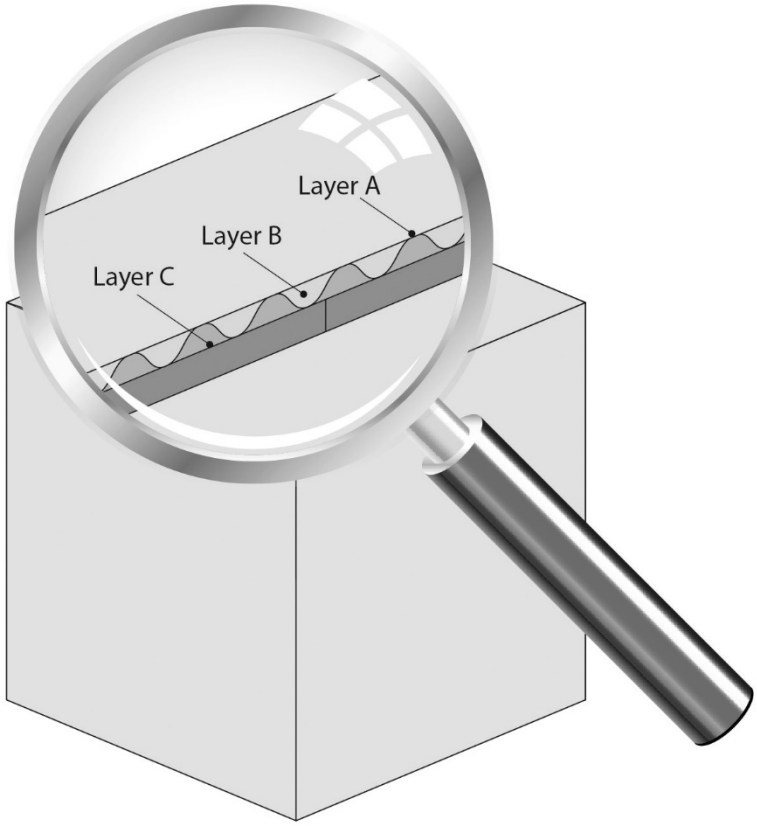

Figure 4

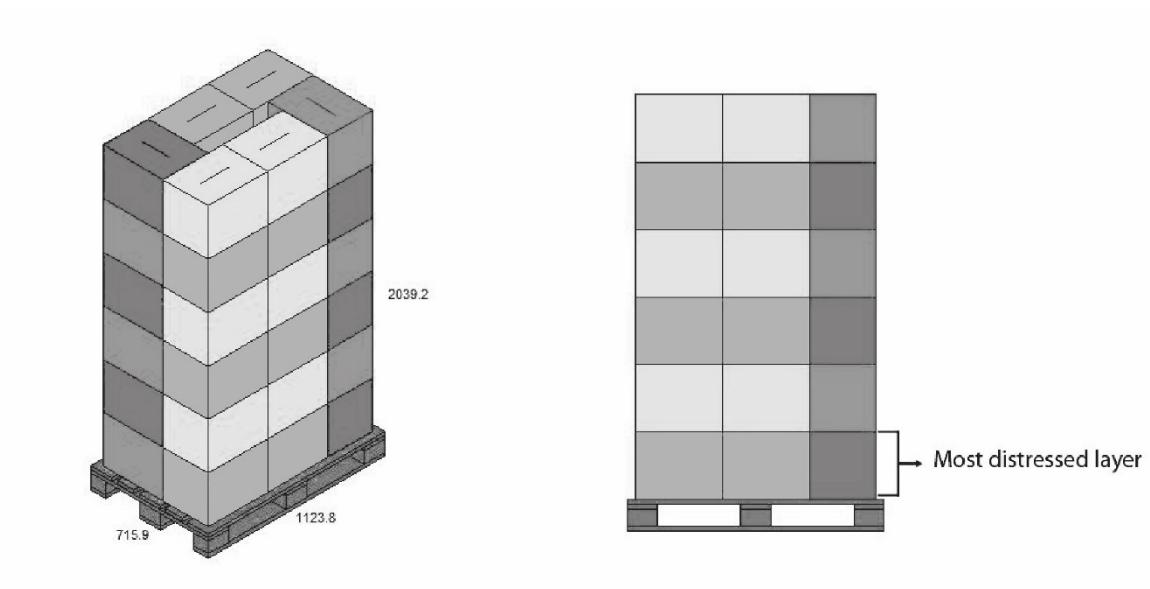

Figure 7

$$\left(\left(\sum_{i=0}^{2} LGsm[1+2i]+Ad\right)\left(2\left(Len+Wid\right)+60\right)+\left(\int_{0}^{2(Len+Wid)+60}\left(LGsm[2]\sqrt{(1+0.16^2*7.281796^2\,\mathrm{Si}\,n[7.281796x]^2)}+\right.\right.\right.$$
$$\left.\left.\left.+LGsm[4]\sqrt{(1+0.2^2*7.78101226^2\,\mathrm{Si}\,n[7.78101226x]^2)}\right)dx\right)\right)\left(Wid+Dep+20\right)/10^6$$

Figure 8

$$\left(\left(\sum_{i=0}^{1} LGsm[1+2i]+Ad\right)\left(2\left(Len+Wid\right)+50\right)+\right.$$
$$\left.+LGsm[2]\left(\int_{0}^{2(Len+Wid)+50}\sqrt{(1+0.2^2*7.78101226^2\,\mathrm{Si}\,n[7.78101226x]^2)}dx\right)\right)\left(Wid+Dep+10\right)/10^6$$

Table 1. Annual needs per packaging code

Packaging Code	Description	Inside Dimensions	Quantity (pcs)
No 1	4x2 kg	400x300x300	48000
No 2	8x1 kg	365X292X227	36000
No 3	6x1 kg	390X320X140	30000
No 4	8x1 ½ kg	390X305X230	43000
No 8	6x1 ½ kg	420X300X160	55000

Table 2. Technical information

Option A			
Layer	**Paper grammage g/m²**	**Sheet Weight (g)**	**Illustration**
A	120	630.33	------Figure 2 around here---------
B	127		
C	100		**Figure 2. Layers**
D	127		
E	100		
Type		Double Sided Layer	
Flute		BC	
Option B			
Layer	**Paper grammage g/m²**	**Sheet Weight (g)**	**Illustration**
A	130	419.95	-------Figure 3 around here--------
B	127		
C	130		**Figure 3. Layers**
Type		Single Sided Layer	
Flute		C	

Table 3. Cost review

Layer	Kind of Paper	g/m^2	Materials Cost/sheet
Option A			
A	Recycled	120	0.2613€
B	Recycled	127	
C	Recycled	100	
D	Recycled	127	
E	Recycled	100	
Option B			
A	Recycled	130	0.1748€
B	Recycled	127	
C	Recycled	130	

Table 4. Comparison

	Kind of Paper	Cost/sheet	Estimated selling price by the packaging manufacturer	% cost reduction for the user
Option A	Recycled	0.2613€	0.5025€	~34.4%
Option B	Recycled	0.1748€	0.3297€	

Table 5. ECT and strength needs

Layer	Kind of Paper	ECT[4]	Strength Needs
Option A	Recycled	≤190kg	**~96.4kg**
Option B	Recycled	≤104kg	

Table 6. Cost difference between Option A and Option B

	Annual Needs (in pieces)	Cost/piece	Total Annual Cost (net)	Money Save
Option A	48000	0.5025€	24120€	8294€
Option B		0.3297€	15826€	

Table 7. Packaging results

	Annual Needs (in pieces)	Cost/piece	Total Cost (net)	Money Save	Strength Needs	ECT
Code: No 2						
Option A	36000	0.2179€	7844€	3146€	~96.4kg	≤196kg
Option B		0.1305€	4698€			≤105kg
Code: No 3						
Option A	30000	0.2090€	6270€	2523€	~130.14kg	≤199kg
Option B		0.1249€	3747€			≤142kg
Code: No 4						
Option A	43000	0.2368€	10182€	4080€	~173.52kg	≤234kg
Option B		0.1419€	6102€			≤190kg
Code: No 8						
Option A	55000	0.2119€	11655€	4692€	~173.52kg	≤236kg
Option B		0.1266€	6963€			≤191kg

Table 8. Flute types – (Source: Foster, 2009)

Flute Type	Flute Thickness (mm)
A flute	4.8
B flute	3.2
C flute	4.0
E flute	1.6