The Packaging Redesign Issue – Space Exploitation and Environmental Benefits

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The Packaging Redesign Issue – Space Exploitation and Environmental Benefits

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<th>Management of Environmental Quality</th>
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<tr>
<td>Keywords</td>
<td>packaging, overpackaging, cost effectiveness, packaging weight, packaging evaluation, packaging effectiveness</td>
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### Table 1. Bottle specifications

<table>
<thead>
<tr>
<th>Description</th>
<th>Material</th>
<th>Volume</th>
<th>Net Diameter</th>
<th>Height</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cylindrical Bottle</td>
<td>PET¹</td>
<td>500ml</td>
<td>63 mm</td>
<td>215 mm</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Description</th>
<th>Material</th>
<th>Volume</th>
<th>Length of the edge of the basis</th>
<th>Height</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rectangular Bottle</td>
<td>PET</td>
<td>500ml</td>
<td>56.74 mm</td>
<td>215 mm</td>
</tr>
</tbody>
</table>

**Cylindrical Bottle:**

---

**Figure 1. Cylindrical Bottle - Front view**

---

**Figure 2. Cylindrical Bottle - Bottom view**

---

**Rectangular bottle:**

---

¹ PET: Polyethylene terephthalate. Its Resin Identification Code (RIC) is number “1”
Figure 3. Rectangular Bottle - Front view

Figure 4. Rectangular Bottle - Top view
Table 2. Packaging analysis

<table>
<thead>
<tr>
<th>Cylindrical Bottle: 20pcs/pack</th>
<th>Rectangular bottle: 20pcs/pack</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pack dimensions (mm) (WxLxH)</td>
<td>Pack dimensions (mm) (WxLxH)</td>
</tr>
<tr>
<td>Pack Volume (m³)</td>
<td>Pack Volume (m³)</td>
</tr>
<tr>
<td>% reduction in pack volumes</td>
<td>% reduction in pack volumes</td>
</tr>
</tbody>
</table>

Cylindrical bottle

<table>
<thead>
<tr>
<th>Pack dimensions (mm) (WxLxH)</th>
<th>Pack Volume (m³)</th>
<th>% reduction in pack volumes</th>
</tr>
</thead>
<tbody>
<tr>
<td>315 x 252 x 215</td>
<td>~0.0171</td>
<td>~18.89%</td>
</tr>
</tbody>
</table>

Rectangular Bottle

<table>
<thead>
<tr>
<th>Pack dimensions (mm) (WxLxH)</th>
<th>Pack Volume (m³)</th>
<th>% reduction in pack volumes</th>
</tr>
</thead>
<tbody>
<tr>
<td>284 x 227 x 215</td>
<td>~0.0139</td>
<td></td>
</tr>
</tbody>
</table>

Figure 5. Cylindrical Bottles - Side view

Figure 6. Cylindrical Bottles - Package Layout

Figure 7. Rectangular Bottles - Side view

Figure 8. Rectangular Bottles - Package Layout
### Palletizing Report

<table>
<thead>
<tr>
<th></th>
<th>Figure 9 around here</th>
<th>Figure 10 around here</th>
</tr>
</thead>
<tbody>
<tr>
<td>Figure 9. Palletizing</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cylindrical Bottle</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Packages/pallet¹</td>
<td>55</td>
<td>70</td>
</tr>
<tr>
<td>Pieces/pallet</td>
<td>1100</td>
<td>1400</td>
</tr>
</tbody>
</table>

|                         |                       |                        |
| Figure 10. Palletizing  |                       |                        |
| Rectangular Bottle      |                       |                        |

¹ Each package contains 20 bottles.
Figure 1-Cylindrical Bottle-Front view

146x154mm (300 x 300 DPI)
Figure 2-Cylindrical Bottle-Bottom view

121x65mm (300 x 300 DPI)
Figure 3-Rectangular Bottle - Front view

92x154mm (300 x 300 DPI)
Figure 5 - Cylindrical Bottles - Side view

234x272mm (300 x 300 DPI)
Figure 6-Cylindrical Bottles - Package Layout

218x167mm (300 x 300 DPI)
Figure 7-Rectangular Bottles - Side view

249x241mm (300 x 300 DPI)
Figure 8-Rectangular Bottles - Package Layout

100x77mm (300 x 300 DPI)
Figure 9-Palletizing Cylindrical Bottle
590x412mm (28 x 28 DPI)
Figure 10-Palletizing Rectangular Bottle

590x412mm (28 x 28 DPI)
V = 4\ast n \ast m \ast p_{cylindrical} \ast height
\[ V = n \times m \times a^2 \times \text{height} \]
### Table 1a. Cylindrical Bottle - Mathematical Relations

<table>
<thead>
<tr>
<th>Total Bottle Height (mm)</th>
<th>Side dimensions (mm)</th>
<th>Bottle shoulder (mm)</th>
<th>Neck (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>150</td>
<td>72,0290</td>
<td></td>
<td></td>
</tr>
<tr>
<td>200</td>
<td>59,3918</td>
<td></td>
<td></td>
</tr>
<tr>
<td>215</td>
<td>56,7369</td>
<td></td>
<td></td>
</tr>
<tr>
<td>250</td>
<td>51,7151</td>
<td></td>
<td></td>
</tr>
<tr>
<td>300</td>
<td>46,4187</td>
<td></td>
<td></td>
</tr>
<tr>
<td>350</td>
<td>42,4805</td>
<td></td>
<td></td>
</tr>
<tr>
<td>400</td>
<td>39,4037</td>
<td></td>
<td></td>
</tr>
<tr>
<td>450</td>
<td>36,9135</td>
<td></td>
<td></td>
</tr>
<tr>
<td>500</td>
<td>34,8443</td>
<td></td>
<td></td>
</tr>
<tr>
<td>550</td>
<td>33,0893</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

---- Figure 14 around here ----

---- Figure 15 around here ----

---- Figure 16 around here ----

---- Figure 17 around here ----

---- Figure 18 around here ----

---- Figure 19 around here ----

---- Figure 20 around here ----

---- Figure 21 around here ----

---- Figure 22 around here ----

---- Figure 23 around here ----
Out[] = 

\begin{align*}
\text{Bottle Height} & \quad \text{Bottle Side} \\
(\text{mm}) & \quad (\text{mm}) \\
150 & \quad 72.029
\end{align*}

144x70mm (300 x 300 DPI)
Out[]:=

\[
\begin{align*}
\text{Bottle Height} & \quad \text{Bottle Side} \\
(\text{mm}) & \quad (\text{mm}) \\
\{200, 59.3918\}
\end{align*}
\]

144x71mm (300 x 300 DPI)
```
Out[10] = 
{
  215, 56.7369
}
```

144x71mm (300 x 300 DPI)
Out[] =

```
{250, 51.7151}
```

144x70mm (300 x 300 DPI)
138x68mm (300 x 300 DPI)
Out[] =

<table>
<thead>
<tr>
<th>Bottle Height</th>
<th>Bottle Side</th>
</tr>
</thead>
<tbody>
<tr>
<td>350</td>
<td>42.4805</td>
</tr>
</tbody>
</table>

144x70mm (300 x 300 DPI)
Out[] =

```
{450, 36.9135}
```

144x70mm (300 x 300 DPI)
Out[] :=

```
{500, 34.8443}
```

144x70mm (300 x 300 DPI)
Out[] =

Bottle Height\n\text{(mm)}
\begin{align*}
\{ & 550, 33.0893 & \}
\end{align*}

144x69mm (300 x 300 DPI)
\[ \begin{align*}
V_{\text{cylindrical}} &= V_{\text{rectangular}} \\
&= \pi \cdot p \cdot l + \frac{1}{3} \cdot h \cdot 2a \cdot p^2 \cdot \pi + \frac{2}{3} \cdot h \cdot 2a \cdot p \cdot l \cdot \pi + \pi \cdot p^2 \cdot h = \\
&= a^2 \cdot (ht1 - h - ht2) + \frac{1}{3} \left( a^2 + 2 \cdot a \cdot p + 4 \cdot p^2 \right) \cdot ht2 + \pi \cdot p^2 \cdot h
\end{align*} \]

so,

\[ a = \frac{-2 \cdot ht2 \cdot p + 3 \cdot \sqrt[4]{\frac{1}{9} \cdot ht2^2 \cdot p^2 - 4 \left( -ht1 - h - ht2 - \frac{ht2}{3} \right)}}{2 \left( 3 (ht1 - h - ht2) + ht2 \right)} \]

351x201mm (144 x 144 DPI)
Table 3. Cylindrical Bottle – Emissions per route

<table>
<thead>
<tr>
<th>CO₂ emissions (gr/km)</th>
<th>Distance (km)</th>
<th>CO₂ emissions/route (kg)</th>
<th>Bottles/ vehicle</th>
<th>Cylindrical bottle - CO₂ emissions (gr/bottle)</th>
</tr>
</thead>
<tbody>
<tr>
<td>264</td>
<td>100</td>
<td>26,4</td>
<td>16.500</td>
<td>1,6</td>
</tr>
<tr>
<td>264</td>
<td>200</td>
<td>52,8</td>
<td>16.500</td>
<td>3,2</td>
</tr>
<tr>
<td>264</td>
<td>300</td>
<td>79,2</td>
<td>16.500</td>
<td>4,8</td>
</tr>
<tr>
<td>264</td>
<td>500</td>
<td>132</td>
<td>16.500</td>
<td>8</td>
</tr>
<tr>
<td>264</td>
<td>700</td>
<td>184,8</td>
<td>16.500</td>
<td>11,2</td>
</tr>
<tr>
<td>264</td>
<td>900</td>
<td>237,6</td>
<td>16.500</td>
<td>14,4</td>
</tr>
</tbody>
</table>
Table 4. Rectangular Bottle – Emissions per route

<table>
<thead>
<tr>
<th>CO₂ emissions (gr/km)</th>
<th>Distance (km)</th>
<th>CO₂ emissions/route (kg)</th>
<th>Bottles/ vehicle</th>
<th>Rectangular bottle CO₂ emissions (gr/bottle)</th>
</tr>
</thead>
<tbody>
<tr>
<td>264</td>
<td>100</td>
<td>26,4</td>
<td>21.000</td>
<td>1,26</td>
</tr>
<tr>
<td>264</td>
<td>200</td>
<td>52,8</td>
<td>21.000</td>
<td>2,51</td>
</tr>
<tr>
<td>264</td>
<td>300</td>
<td>79,2</td>
<td>21.000</td>
<td>3,77</td>
</tr>
<tr>
<td>264</td>
<td>500</td>
<td>132</td>
<td>21.000</td>
<td>6,29</td>
</tr>
<tr>
<td>264</td>
<td>700</td>
<td>184,8</td>
<td>21.000</td>
<td>8,80</td>
</tr>
<tr>
<td>264</td>
<td>900</td>
<td>237,6</td>
<td>21.000</td>
<td>11,31</td>
</tr>
</tbody>
</table>
Introduction

In recent years, the evolution of economy and the resulted overconsumption and overproduction phenomena, contributed inevitably in environmental aggravation worldwide (Taghikhah et al., 2019). Environmental protection and sustainable development have become very popular in recent years. Among others, the development of e-commerce that has emerged as a result of growing distribution channels, has caused a tremendous increase in the consumption of packaging materials. Inevitably, packaging industry has evolved worldwide (Fan et al., 2017). The evolution of express delivery worldwide which is the result of the fast growth of e-commerce affects the environment in many ways. As described by Kang et. al. (2021) the express delivery sector in China produced in 2018 a total of nearly 9 Mt of scrap packaging materials. The amount is enormous especially if we consider that it doesn’t include the amount of waste packaging materials generated by other functions of the supply chain. Logistics industry has noticed the importance of packaging in environmental aggravation and green packaging is constantly evolving (Georgakoudis et al., 2018; Hao et al., 2019, Sumrin, et al., 2021).

Careful packaging redesign may contribute to environmental protection and reduce the corresponding environmental impact (Gustavo et al., 2018; Geueke et al., 2018). In addition, various changes in packaging materials, affect not only the environmental impact of packaging but also the sustainability perceptions of the consumers and the perceived taste and quality (Koutsimanis et al., 2012; Steenis et al., 2017). As described in a research conducted by Del Borghi et al. (2014), that present the results of a Life Cycle Assessment (LCA) on a number of Italian tomato-based products, an optimization of the packaging materials (in primary, secondary or tertiary packaging) contributes to a reduction in their total weight and further reduction to the overall environmental impact. Moreover, Landi et. al. (2020) present a methodology dealing with the redesign of sustainable packaging for household appliances. According to their research a simple packaging redesign is possible to reduce the environmental impacts by nearly 15%. In addition, Balwada et. al. (2021) have developed a model for recycling the plastic waste generated from the packaging industry. The method includes the use of Analytical Hierarchy process in order to find the best waste collection method. Therefore, the idea of bringing innovative solutions
into the design, redesign of packaging solutions is not new, however it requires further empirical studies to demonstrate the opportunities offered.

The goal in packaging redesign is to find the right balance between an eco-friendly and a fully functional packaging without compromising other traditional requirements (i.e. protection, marketing characteristics and logistics-related features) (Bovea, 2007, Prakash & Pathak, 2017; Sumrin, et al., 2021). Several researches have also revealed that targeted changes in packaging materials might contribute in better environmental performance. For example, Bertolini et al. (2016) argue that the multilayer carton system causes less environmental impact among other solutions i.e. HDPE (High-density Polyethylene) and PET (Polyethylene terephthalate) systems and thus it proves to be the most environmental-friendly alternative for milk packaging. In the same manner, Sohrabpour et al. (2016) developed a method for improving the existing packaging design of Tetra Pak taking into account the individual needs of the entire supply chain. Therefore, we believe that the specific method enables improved supply chain efficiency, taking into account the product, the processes and cost. The method mainly aims to improve the supply chain efficiency and ameliorate its environmental performance.

As described by Twede, (2009), after its use, packaging contributes to the overall social costs through disposal, recycling or reusing processes. Here, we may add the cost resulting from the transportation processes of the packaging or the packaged product as well. The more the items are being carried per route, the less the shipping cost is per item. Therefore, in relation to the environment, the more items are being carried per route, the less energy and CO$_2$ are required per unit of product carried or stored.

It should be stressed that environmental protection, is not solely related to the packaging materials. Plenty of researches have been conducted on the environmental modelling subject dealing with the minimization of the production of undesirable factors (Seiford and Zhu, 1999, Fare and Grosskopf, 1996, 2000, Wu et al., 2016) whereas Zoriejhabib et. al. (2021), developed and discussed a model on how to define an effective environmental efficiency model.

The factor of low-carbon emissions is having its significance as well. Several factors affecting consumers’ willingness to pay for low-carbon products have been
investigated and determined by Liu et al. (2017). Such factors, include the delivery speed of these products and consumers’ degree of satisfaction. The carbon emissions issue seems to be of great importance from many aspects. Raghutla and Chittedi (2021), have discussed the relation between the financial development and energy consumption on the one hand with the economic output and carbon emissions on the other in five emerging economies. They conclude that since economic growth is related with increased carbon emissions due to increased energy consumption, the countries should focus on green technology in order to decrease carbon emissions while maintaining economic growth. Furthermore, the adoption of green practices and the reduction in fuel consumption, except for the expected environmental protection can result in significant cost savings for the companies (Gupta and Singh, 2020).

The emerging environmental issues dictate that the scientific community should lean over these issues and contribute in any way possible for the alleviation of these phenomena. The present research has been designed in order to investigate the maximization of the exploitation of the utilized space in the supply chain. The outcomes reveal the reduction of the energy and CO$_2$ required per unit of product carried or stored, giving further evidence concerning the economic benefits for the industry and the participants of the supply chain.

The present investigation begins with a literature review on packaging sustainability trends, a brief analysis of the Eco-packaging concept and a description of the relation between the transportation and the corresponding CO$_2$ emissions. At the second part, the Case Study includes the comparison of two different bottle cases and the discussion that follows, shows the economic benefits for the company and the reduced CO$_2$ emissions that are strongly related with the environment. The limitations of the research as well as the concepts for further work are being presented at the last section of this paper.

1. Literature Review

Packaging sustainability trends
4

The packaging redesign concept is a complicated issue. Due to the fact that packaging itself affects a number of logistics functions within the supply chain, any changes in packaging strongly affect the participants in it. Hyde et al. (2001) state that an essential dialogue between producers, retailers and consumers may contribute to several issues such as the packaging redesign. According to Walker et al. (2021) in order to achieve better results concerning a more sustainable future on the use of plastic, a mixture of measures might need to be combined including the use of biodegradable materials, retail pricing as well as bans and taxes posed by the individual governments. In the same manner, Wikström et al. (2014) argue that one of the most significant packaging problems that should be faced is the aim to avoid waste. For this reason, the connection between packaging design and waste should be properly evaluated and valued by the individual participants involved in the supply chain i.e. suppliers, products and packaging manufacturers, wholesalers and retailers and final consumers.

The environmental protection may come as a result of a higher protection offered by the redesigned packaging to the product itself. As described by Williams et al. (2012), a proportion of 20-25% of household food wastes could be related to its inappropriate packaging (e.g. oversized packaging, packages difficult to empty etc). An efficiently-designed packaging that improves protection, reduces damage throughout the supply chain, improves ventilation and temperature control, informs the consumer in an effective way, facilitates handling and usage by the final consumer, can contribute in overall waste reduction (Verghese et al., 2015; Georgakoudis et al., 2018).

The industry is currently making real progress on the packaging field. In 2013 NewPage Corp. earned the Sustainability Award in the Ameristar 2013 competition for its “LittleFoot 100% Compostable Packaging Barrier Product”. The above packaging is fully compostable and manufactured by combining paper and metalized cellophane, which makes it possible to avoid the use of foil or other polymers. Its composition ensures high protection from oxygen and moisture for the product while offering a notable printing surface and distinct appearance.

For what is relevant to the retailing sector, packaging remains a significant element especially in cases such as the shelf-service supermarkets. Except for its role in marketing that is crucial in order to achieve increased sales, packaging further communicates details to the consumers including the ingredients, the origin, the shelf
life of the product itself. However, one of its main functions is the ability to provide a nearly perfect arranged place (i.e. the supermarket). Thus, the above elements clearly describe the huge responsibility of supermarkets for the reduction of packaging waste which could succeed only if the participants recognize the diversity of roles packaging is playing in the supply chain (Sattlegger, 2021).

Announcements made by big companies clearly show the way towards packaging sustainability. A remarkable example is that of Sainsbury which during the last decade has made some serious changes such as the decision to increase the use of recycled and recyclable packaging materials. (“J Sainsbury Plans to Reduce Store Brand Packaging”, 2011). More recently, the same supermarket has announced that they are looking to remove entirely the plastic bags from all their supermarkets for fresh vegetables, fruits and bakery and replace them with paper bags (Evening News, 2019). Similarly, Boots has also announced that they will replace their plastic bags and replace these with brown paper bags by 2020 (Kollewe, 2019).

In the same manner, the US retailing giant Walmart decided to engage in packaging sustainability. One of its main objectives was to redesign the shoe boxes used throughout its US shops. According to Kalkowski (2012a) the new design economized on paper by 692 tons approximately, within the first 10 months in 2011. Furthermore, the company decided to ask its toy suppliers to replace the wire ties used to prevent the toy from moving in the box with ties made by natural fibers. In this way, in 2 years’ time approximately, the Walmart products managed to save up to 1.6 billion feet of wire.

Lastly, it should also be considered that more often than not packaging cannot be substituted and that in many cases companies cannot use lighter, bio-degradable or packaging made from recycled materials. It may be easy to find new innovative and sustainable ways to pack shoes, for example, or use new wrapping materials and lighter corrugated boxes to protect electronic equipment and detergents, for instance, but is not always easy to substitute primary packaging for food (e.g. biscuits, rice, flour, etc.) (Kalkowski, 2012b).

**Eco – Packaging**
It should be noted that in most cases packaging is of high importance for the consumers, since in addition to the offered protection, it also differentiates the product in the market. Muratoglu, vice president of marketing and product management at Tetra Pack Inc. supports: “... packaging can serve as a point of differentiation and generate further value for consumers” (Furhman, 2011). In the same manner, according to Williams et al. (2008), packaging except for creating a product brand, it is also the mean to communicate with the final consumer. More recently, research is conducted into extending the understanding of the role of packaging from its intending use to keep a product safe, to facilitate its transportation, the message it sends to the consumers and the way in which it could capture their attention through different aspects of design (Spence, 2016).

Although according to the classical notion the main target of packaging is to protect the product, one should bear in mind that eco-packaging should gather different attributes, rendering it not only proper but also sustaining its environmentally – friendly aspect, while at the same time serving its fundamental purpose (Jedlička, 2009). However, despite the fact that both governments and consumers keep asking for more “green” packaging, what an industrial customer needs is an enticing packaging for the products.

In addition, consumers require that the product should be properly packaged and marketing departments request that packaging should be luxurious and alluring enough to promote. The industry should be able to adapt to the various needs and requirements of the market concerning environmental concerns (Hänninen and Karjaluoto, 2017). The dilemma is obvious for packaging companies as they are obliged to combine the conflicting demands, which means that a packaging solution must be found, one that should be “green”, attractive, provide proper protection to the product and strengthen brand image (“Sustainable Packaging”, 2004). As described by Henry Renella1 (“Luxury Consumers Prefer Subtle Sustainability Messages on Packaging”, 2011) although a luxury brand should undoubtedly be aligned and use sustainable packaging, the image and impression of the product’s luxury packaging should stay intact.

1 Senior vice president of New York-based Estee Lauder’s Global Packaging development.
Another important aspect that should be taken into account is the one described by Williams and Wikström (2011). They argue that although in the past the idea was to use less (packaging) and recycle more, the new environmental trends suggest that the environmental protection that packaging itself offers should be the focus. They also recommend that the industry reconsider its practices and if necessary be ready to increase the environmental impact from the new packaging, should this lead to the reduction of product losses. Given the increasing demand for more products, the idea is to estimate and compare the environmental consequences between more and of better-quality packaging and food losses before making the right decisions. The integration of packaging sustainability requires changes and partly or totally redesigning of production, consumption and waste management (Čuček et al., 2012).

There is a general perception that there is an increasing interest in environmentally friendly (sustainable) packaging in comparison with regular packaging (Martinho et al., 2015; Magnier and Schoormans, 2015). Thus, it is common for companies to introduce sustainable packages since the consumers are becoming more and more interested in the concept of sustainability (Olsen et al., 2014, Georgakoudis et al., 2018). However, the acceptability of an eco-friendly packaging -which may be differentiated in materials, shape, innovative closure designs etc.- is strongly influenced by several individual factors such as attitudes, environmental culture and concerns and willingness to pay (Prakash and Pathak, 2017). Hao et al. (2019) argue that convenience, reusability and product protection offered by the packaging are the most important characteristics for the consumers, with regard to green packaging. Herbes et al. (2018), describe that consumers are more interested on end-of-life attributes of packaging rather than on renewable origins, manufacturing processes or transportation methods and procedures. Sumrin, et al. (2021), bring the following characteristics for eco-packaging: first, the impression the product gives regarding the environmental responsibility and quality, followed by the recyclability, reusability and biodegradability. Other characteristics brought in their study are: the environmental friendly technology used to produce the packaging, followed by characteristics such as market appeal and the price of product.

Steenis et al. (2018) state that the level of success of sustainable packaging and the gains for the environment depend not only on the characteristics of the packaging itself, but also on consumers’ willingness to purchase environmentally friendly packaged products. It should be noted that the consumers’ level of awareness and
environmental concern strongly affect their buying decisions. An interesting aspect is that of Gustavo et al. (2018) who argue that for the concept of packaging redesign the potential economic gains are of great importance for the participants, while the benefits for the environment will be the result and not the basic motivation to proceed with it. It should be noted that the aspects of the consumers, concerning the aggravation of the environment caused by the use of packaging is not the same for the different packaging materials. For example, Klaiman et al. (2016) conducted a research where it is discussed that the consumer willingness to pay in order to recycle packaging materials is higher for plastic packaging than for any other material. On the other hand, despite the fact that most of the consumers are keen to use green packaging and contribute in environmental protection, their willingness to pay for it is not clear (Nordin and Selke, 2010). Lucas (2013) explains that consumers keep asking for more “green” products yet they also expect that the cost should be absorbed by the industry. In addition, sustainability is a priority for consumers, which strongly affects their consuming habits, aiding environmental protection (Goodrich, 2012; Bemporad et al., 2012). However, the citizen’s active participation in various environmental activities is of the utmost importance at this point, since it ensures that well-informed citizens will seek and find ways to support sustainability. According to Magnier and Crié (2015), the consumers perceive sustainable or eco-designed packaging as “a design that evokes explicitly or implicitly the eco-friendliness of the packaging”.

Another aspect of packaging reduction, is that of the adoption of zero packaging. As Beitzen-Heineke et al., (2017) describe, the further adoption of this method requires influencing consumer behavior while convincing suppliers to re-structure their packaging practices. However, a significant milestone in order to achieve environmental and social benefits will be the high service level of the zero-packaging stores that should be equivalent to the conventional supermarkets. On the other hand, there is a view that packaging itself reduces wastage by its role in the protection and preservation of products (Georgakoudis, 2014). For example, as cited by Marsh and Bugusu (2007), using proper food packaging can extend shelf life by delaying product deterioration, maintain quality and safety of food and at the same time facilitate transportation and storage of the product itself. Verghese et al. (2015) and Lindh et al. (2016), describe the role of packaging into decreasing food waste throughout the supply chain by reducing damage due to improper handling or transport accidents as well as extending shelf life.
In addition, packaging saves considerable emissions due to its role into preventing food waste, thus contributing in environmental protection by further minimizing the environmental aggravation of the wider sector of the food industry (Schmidt Rivera et al., 2014). Grönman et al. (2013) developed a framework for designing sustainable food packaging considering the entire life cycle of the product-package combination. The main aim is to prevent food losses through the appropriate package design, further contributing in environmental protection.

**Transportation and CO₂ emissions**

The problem of CO₂ emissions and environmental aggravation is receiving considerable attention worldwide while it appears to concern governments, industry and the society more and more in recent years. The contribution of human activity (from the burning of fossil fuels) to global climate change has emerged as a key issue (Gui et al., 2014). For example, in European Union around 25% of greenhouse gas emissions is related to transportation activities (EU Transport GHG, 2007) while around 14% of the total Swedish CO₂ emissions are related to transport sector (Hu et al., 2019). For this reason, there is a global trend to address the phenomenon by reducing the greenhouse emissions and the consequences resulting from the industrial and logistical activities. There are multiple researches discussing the need to face the problem of carbon emissions in order to protect the environment. Other researches deal with the allocation of CO₂ emissions in transportation routes (Leenders et al., 2017). The transport sector which is heavily dependent on fossil fuels faces serious problems in reducing its environmental impact (Fridell et al., 2019). Singh et. al. (2021), argue that among others the most significant criteria in selecting a sustainable transport system is the cost of fuel, energy efficiency and CO₂ emissions. The use of new technologies and major improvements in vehicle operating efficiencies have been promoted as necessary steps in this direction (Du et al., 2019, Kazancoglu et al., 2018).

Several efforts on the reduction of total greenhouse gas emissions have been conducted in recent years, in different fields. Among others, the International Maritime Organization has agreed in 2018 to force the reduction of CO₂ emissions. This policy resulted in a significant decrease in annual CO₂ emissions that was partly the result of important technological improvements and various changes in
scheduling and network designs leading to less distance travelled (Cariou et al., 2019).

For what is relevant to packaging, the optimization of the packaging design is an emerging issue. Packaging design can contribute in a positive way in environmental protection through targeted changes that could decrease the environmental footprint of the product itself. Changes in shape design could produce significant savings in space capacity. As it is shown below, even the smaller savings in space, could produce significant results and reduced CO$_2$ emissions per product carried per route.

2. The Case Study

The following Case Study is an introduction to the packaging redesign issue. Its purpose is to demonstrate that a detailed analysis and a careful redesign of a product’s packaging, may result to cost savings through capacity gains in transportation and warehousing as well as to benefits for the environment and reduced CO$_2$ emissions. All the above, in turn, could lead to benefits for the final consumer and the community.

In this Case Study, two different options of a bottle as primary packaging are investigated in terms of: shape and space utilization and an analysis in terms of cost, weight, CO$_2$, etc. can be observed. The first option is a regular cylindrical bottle while the second, alternative option is a rectangular shaped bottle. The two bottles are having the same capacity while the main aim is to provide improvements in the utilization of the area and present the gains resulting from this procedure. The comparison between the bottles, provide the strengths and weaknesses of each option.

Wolfram Mathematica v.12 was used to calculate the relation between the size of the rectangular bottle and its height so that the volume between the initial bottle (i.e. cylindrical) and the final bottle (i.e. rectangular) is equal. A code in Mathematica has been developed in order to calculate the relation between the elements mentioned above.

As a second step, Rhinoceros v.6 CAD software has been used for the design of the bottles in order to ensure the accuracy of their dimensions.

In addition, TOPS Pro software has been used to estimate the final pallet pattern.
The analysis shows that a better exploit of the space (vehicle, pallet, secondary, packaging etc.) could further offer significant economic benefits for the company with respect to transportation and warehousing.

**Mathematical Modeling**

In order to retain the same volume in both containers ($V_{cylindrical} = V_{rectangular}$), the following mathematical relation between the height and the side dimensions of the rectangular bottle, is defined:

![Figure 13 around here](image)

where,

- $\alpha$ = length of square base of rectangular bottle
- $p_1\alpha$ = body radius (cylindrical bottle)
- $p$ = neck radius
- $h_1\alpha$ = body height (cylindrical bottle)
- $h_2\alpha$ = shoulder height (cylindrical bottle)
- $h_{t1}$ = total height (rectangular bottle)
- $h_{t2}$ = shoulder height (rectangular bottle)
- $h$ = neck height

A code in Mathematica has been developed in order to calculate the relation between the height and the overall dimensions of the final bottle.

The outcomes for the rectangular bottle are presented below:

![Table 1a around here](image)
Description

The cylindrical bottle is a regular 500ml plastic bottle containing liquid (water). The alternative container, is a rectangular plastic bottle of 500ml. For this research, the height for both bottles remains the same i.e. 215mm. The specifications of the bottles are presented in Table 1.

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

The rectangular bottle has been designed in order to have the same capacity with the cylindrical bottle. However, the new shape allows the placement of the pieces in such a way that saves a significant amount of space. In this research, we pack 20 pieces of bottles in both cases. In order to retain the bottles together in a solid pack we are using shrink film. The results are shown below in Table 2:

-------------------Table 2 around here-------------------

If we further check the palletizing of both solutions, we can see the space amelioration. In the present analysis we use a Europallet (dimensions 800x1200mm). We also set the height of the pallet to be no more than 1220mm and to have no overhang (0mm). In the above scenario, a Europallet can carry 1100 cylindrical bottles and 1400 rectangular bottles. Thus, there is a significant increase of the bottles carried per different bottle design, of 300 pieces, an increase of ~27%.

The general form to estimate the total pack volume of the cylindrical bottle solution, is the following:

-------------------Figure 11 around here-------------------

While the general form to estimate the total pack volume of the redesigned bottle solution, is the following:

-------------------Figure 12 around here-------------------
where,

\[ n = \text{the number of bottles per row} \]

\[ m = \text{the number of bottles per column} \]

\[ p_{\text{cylindrical}} = \text{radius of the basis of the cylindrical bottle} \]

\[ \alpha = \text{the length of the edge of the basis of the rectangular bottle} \]

\[ \text{height} = \text{total bottle height} \]

### 3. Conclusion

The above analysis clearly shows a number of issues that could be further discussed. Based on the results, we could argue that by making changes at the shape of a container (e.g. bottle, as primary packaging), the gains for the industry, the environment and the community could be significant and easily noticeable. We conclude that major changes in the body of a bottle container, may result into space ameliorations impacting the warehousing and the transportation processes.

It should be underlined that any changes in the shape of the bottle are of great importance and should take into consideration different elements such as the needs of the consumers, the requirements of the supply chain, the various marketing requirements and various economic factors. The packaging redesign process meets significant difficulties especially when the company doesn’t make frequent changes at the image of the product since this might further affect the consumer behavior.

Since fuel consumption is an emerging problem nowadays and the protection of the environment is becoming more and more important for most citizens worldwide, the reduction of CO\(_2\) emissions is having an important role. If we add the economic benefits that may result, packaging redesign is a concept that needs to be addressed seriously.

The analysis reveals that by using the newly designed bottle, the total packaging volume (containing 20 pieces of bottles) can be reduced by nearly 19%. This reduction in total packaging volume, can further increase the total bottles carried per pallet by 27%. Of course, the pallet type used in this case study was the same in both cases, i.e. Europallet.
The gains coming from the space amelioration, are not limited just to economic terms (as we’ll discuss below) but could also bring further environmental gains. By making a simple scenario where the vehicle carries 15 pallets of the specific product and based on the above analysis, we can conclude that while in the regular-bottle scenario the vehicle carries 16,500 bottles, in the rectangular-bottle scenario, the same vehicle (carrying the same number of pallets) could carry 21,000 bottles. Furthermore, by increasing the number of bottles carried per route, a company could reduce its carrying costs per item. Assuming that the carrying cost for a destination is 200€, the cost per item is: 0.012€ for 16,500 regular bottles while it is: 0.0095€ for the rectangular bottle. It can be easily estimated that the cost is decreased by ~21%.

In addition, it could be easily concluded, that if we succeed to carry more products per route, then the CO₂ per product could be reduced, having in this way, a stronger positive impact for the environment. For example, a van with an average fuel consumption of 10L/100km, produces 264gr of CO₂ per km or 26.4kg of CO₂ per 100km (http://ecoscore.be/en/info/ecoscore/co2). In our example, if the vehicle carries 16,500 bottles for a distance of 100km, then the equivalent CO₂ per bottle is 1.6 gr, while for the rectangular bottle, the CO₂ per item is reduced at 1.26 gr. Here again, based on the above scenario the CO₂ is decreased by ~21%.

4. Limitations and Further Work

The above analysis, is focusing on the shape of the bottle and the gains that could result from the redesigning of the bottle itself. This study proposes a methodological approach to support, promote and evaluate major changes in packaging design in an effort to achieve significant environmental gains in the supply chain.

This research compares two bottles of different shape in terms of pallet capacity and environmental impacts. The study compares an existing bottle/container with an improved solution. The proposed solution was designed in order to have the same
volume with the existing container. The results may be used by industrial users and manufacturers to improve their packaging performance and evaluate packaging redesign actions in terms of cost and environmental protection.

The analysis could be further extended by adding additional elements such as the interconnection between the amount of raw materials needed for the new bottle and the gains resulting from the space amelioration caused by this process.

The analysis can also be extended by investigating the use of alternative packaging materials. For example, the use of proper packaging offers the desired protection and prevents the physical and chemical deterioration of sensitive food products such as cheese or cold meat. However, although the use of synthetic films is the most common process since it provides the desired protection in such kind of products, they are not friendly for the environment due to their low biodegradability and this fact have raised serious environmental concerns (Jafarzadeh et. al., 2021). Thus, the use of alternative packaging materials in relation with a sophisticated system with main purpose the reduction of CO\textsubscript{2} emissions could further extend the above analysis.

Further work, could include the use of other types of pallets, in order to make strong comparisons on how the rectangular bottle could contribute in further gains for the industry and the community. The research shall also be extended by examining different bottle shapes.

It should be noted that as the environmental problems are becoming more and more emerged, further work could also include the examination of the gains on CO\textsubscript{2} emissions that are related to the space amelioration concept. Using more space, transporting more products at any one time within a pallet, would bring transportations and product handling benefits.

Twede (2009) describes that although all products are packaged in some way and despite the fact that their parts could also be repacked several times throughout the supply chain (until they are being transformed into a final product), this cost is not always visible since, in most cases, it is embedded in the manufacturing cost.

An important issue is the kind and the characteristics of the packaged product as well. For example, according to Griff (1997) the beer industry and the soft-drink industry are different with peculiar characteristics and special packaging needs. Although, the soft-drink industry can successfully operate under a franchise system (where independent local bottlers produce the item under the supervision of the parent company), the beer industry appears to operate in a different way, while the firms produce the beer in their own facilities (the vast majority ~90% of the beer is
made by the top 10 companies). This in turn, means that the supply chains for these products appear significantly different, since the soft-drinks can be produced and shipped locally, while the beers should be shipped and distributed in wider areas and longer distances.

Twede (2009) supports that because of its heavier weight, packaging made from steel have been substituted by aluminum that is lighter -though more expensive- and can be easily recycled. However, the use of plastics is rising while the new manufacturing processes and the use of innovative materials provide all the mechanical properties (such as desired permeability) required for the intended use.

In addition, the on-the-go food consumption trend which has grown during the last decade boosts the use of single use plastic packaging (Ncube et. al., 2021). This waste which comes as a result of our modern way of life aggravates the environment causing land and water pollution. The governments worldwide are taking measures in order to confront the problems arising. Such measures include the promotion of recycle and reuse by providing economic incentives to the parts involved. The level of public acceptance of such measures, in combination with the environmental gains and the extra cost generated for the industry, could be further investigated.

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