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ANALYSIS OF THE PACKAGING OPTIMISATION PROCESS USING A SELECTED PRODUCT AS AN EXAMPLE

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Purpose: Packaging plays a key role in modern industry, serving not only a protective function, but also marketing, information and environmental functions. This literature study on packaging aims to understand packaging technologies, innovations being introduced and the application of lean principles to optimise packaging processes. The introduction to this study includes an overview of the basic functions of packaging, its impact on the product life cycle and the growing importance of sustainability in the context of ecology. As global markets become increasingly competitive, companies are looking to minimise costs and waste by implementing lean methodologies. A key aspect of the study is to identify the most effective tools used in lean packaging that contribute to supply chain optimisation, cost reduction and increased product quality. An analysis of the literature will provide an understanding of how innovative packaging approaches can enhance the competitiveness of companies in the global marketplace. The article discusses the various types of packaging used in the company. It focuses on the implementation of lean packaging principles to minimise waste and increase the efficiency of packaging processes. One of the key elements of the article is the presentation of a new type of packaging that has been designed to increase the number of packages that fit on a single pallet. This makes it possible to reduce the amount of 'air carried,' which translates into optimised transport and storage costs. The new packaging is characterised by its ergonomic shape and the possibility of greater compression, allowing more efficient use of pallet space. The implementation of this innovative solution contributes to a significant improvement in logistical efficiency within the company.
Design/methodology/approach: This article briefly reviews the literature in the area of lean management and lean packaging and packaging concepts. A simulation method - mathematical calculations - has been used. Observations were also made of packaging methods and an analysis of the packaging procedures and guidelines in place at the company under study.
Findings: The aim of this paper was to analyse the packaging of clips in the company under study using lean packaging tools and a simple simulation of the proposed solution options.
Practical implications: Companies should constantly analyse the packaging solutions they and their competitors use and aim to exclude those that are harmful to the environment and not cost-effective for the company itself. Other packaging-related problems, besides under-utilisation of loading space, include: inadequate securing of goods, poor labelling of packaging (incomplete information about the contents of the package on the label), half-empty trucks due to the inability to stack pallet units, negative environmental impact, etc. Most of these problems lead to financial losses for the company, which is why it is important to act preventively and design product packaging wisely with the help of specialists, as this will lead to tangible benefits.

Originality/value: Since the selection of appropriate packaging, the arrangement of goods in individual and collective packaging and their adequate protection are aimed at maximising the number of packages on the pallet, reducing transport and storage costs and the risk of damage to the goods, the topic addressed is relevant to the activities of the company under review.
Keywords: lean management, lean packaging, packaging, space optimization.
Category of the paper: case study.

1. Introduction

Regardless of the type of goods a company intends to store, sort and deliver to its customers, transport packaging is an absolute must in manufacturing, trade and logistics. Today, approximately 97% of all goods manufactured worldwide require packaging, and a large percentage of these cannot be transported without packaging. The packaging itself has functions: informational, manipulative, protective, transporting, but also marketing functions: the attractiveness of the packaging determines the amount of sales, and many products, such as alcohols, sweets or cosmetics, are bought more because of the packaging than the content itself (Kozar, 2023; Motowidlak, 2023; Kamińska, 2020; Świętoń, 2020; Dudziński, 2014). This is because in marketing, 'it is assumed that packaging gives the commodity its "personality", becoming its business card enabling the consumer to notice "his" commodity and recognise it among many similar ones (Malinowska, 2011; Ratajczak, 2021). Packaging is an essential element for both transport and storage management, and performs many functions that benefit both the packaged goods and the environment. The main participants in the global packaging market are the European Union countries, the United States, Japan and China. In contrast, the US is the largest user of packaging, followed by China, which will overtake the US, according to a report compiled by Smithers Pira (Rodriguez, 2024). The US packaging industry is estimated to grow from 713.7 billion units in 2021 to 764.5 billion units in 2026[1]. The global packaging market is forecast to grow at a compound annual growth rate (CAGR) of 3.9% between 2023 and 2028. Growth is expected to slow to a 2.1% CAGR between 2028 and 2050. The global packaging market is expected to reach US$2.23 trillion by 2050. Per capita consumption of packaging is expected to increase globally by 2050, with the fastest growth rates in low- and middle-income regions. These markets have significant room for expansion as more consumers move from minimal or informal packaging solutions to more standardised, formal packaging options (Rodriguez, 2024). Changing demographics and differences in packaging needs mean that packaging consumption markets vary around the world. The packaging industry is constantly evolving, influenced by demographic changes, economic development and consumer demands. Low- and high-income countries show different

[1] https://www.bonfiglioliconsulting.com/en/learning/whats-next-trends-and-opportunities-in-the-us-packaging-industry/, 9.2024.

packaging needs; for example, the desire for sustainability and premium packaging in high-income countries is not the same as in lower-income regions. These key trends are studied in detail, along with the impact of population growth and decline, as well as demographic changes on product consumption and packaging development. In 2020, more than 6.5 million tonnes of packaging entered the Polish market (GUS, 2022). According to the new proposal, all packaging on the EU market must be recyclable or reusable by 2030 and packaging waste is to be reduced by 10% by 2035[2]. The structure of the packaging market by the construction material used clearly shows that the packaging produced globally is mainly made of paper and cardboard and plastics. 40% of the plastic and 50% of the paper used in the EU is used for packaging (Projekt rozporządzenie PPWR, 2022). Metal packaging also occupies a fairly significant share of the market (17.3% world, 18.2% Europe), while only a small amount of packaging is produced from glass, wood or other materials. The consumption of packaging both in Poland and globally is increasing year by year. Between 2009 and 2019, the amount of packaging waste generated in the European Union increased by 13.6 million tonnes (20.5%) (GUS, 2022). In Poland, the mass of municipal waste generated in 2021 was 13.7 million tonnes, an increase in generation of more than 4% compared to the previous year[3]. According to experts' predictions, in the coming years, the Polish packaging market will approach the markets of developed Western European countries in terms of structure. The share of paper and cardboard packaging will increase by about 4-5%, while the share of metal packaging will decrease. Such a high consumption of packaging in both the largest world economies and developing economies drives the packaging market and forces it to provide new solutions that will translate into benefits for producers, consumers, packaged goods and the environment. The multifaceted nature that packaging must have in today's economy makes it an extremely interesting topic to research and then use as an element to improve logistics processes in companies and supply chains (Sastre, 2022).

2. The role of packaging and lean packaging

Packaging logistics plays an important role in today's economy, as well-chosen packaging can significantly increase a company's market share (Bányai, 2023; Morashti, 2022). According to the Polish Committee for Standardisation, packaging is a product used to protect other products from damage, as well as to protect the external environment from any impact of the packaged product. DIN 55 405 specifies that packaging consists of (Wyszkowska 2013):

[2] https://www.rajapack.pl/blog-pl/przepisy-dotyczace-opakowan-w-roznych-krajach-jak-dostosowac-sie-do-miedzynarodowych-wymogow-prawnych, 9.2024.
[3] https://ungc.org.pl/wp-content/uploads/2024/06/Gospodarka_obiegu_zamknie%CC%A8tego_w_opakowaniach.pdf, 9.2024.

- packaging media - products of packaging materials that are designed to cover and hold packaged goods together,
- packaging materials - the materials from which packaging is made,
- auxiliaries - any means which, together with the packaging means, serve to package and close and prepare the goods for shipment.

Packaging plays a very important role in supply chains, as without transport packaging that is properly designed and manufactured, the proper functioning of the supply chain is not possible (Biuletyn…, 2016, p. 2). They perform extremely important functions in companies. Packaging is an element that conditions the correct and efficient flow of transport, production and also storage processes (Jedlinski, 2021).

The following packaging functions can be distinguished (Wozniak, 2011):

- production function - it allows the preparation of the right amount of products, components needed at the input of production, and the reception of the right amount of goods at its output,
- marketing function - in marketing terms, packaging plays an important role. It enables the product and the company to stand out from the competition,
- utility function - this refers to any reuse of packaging by the buyer, or use for other purposes,
- logistical function - this function facilitates all transport, storage and handling operations. Packaging is most often provided with special logistics labels that facilitate the tracking of goods in the system and also allow the identification of warehouse locations.

Packaging in terms of logistics should fulfil a number of functions, which include (Bendkowski, 2002; Cyrek, 2015):

- protective function - aimed at protecting goods from deterioration, or loss of quality, caused by mechanical, climatic or human factors,
- transport and storage function - aimed at facilitating all transport and storage processes through the appropriate dimensions of packaging, adapted to the area and capacity of transport and storage means,
- handling function - to facilitate mechanical or manual handling work,
- recycling and environmental function - a function that allows packaging to be reused for its original purpose or for other purposes, and to be disposed of appropriately,
- information function - packaging is a kind of information carrier. This function refers to the control of processes related to the protection of product quality throughout the production cycle.

The broad set of packaging functions translates into the maintenance of a positive level of customer service, allowing the logistical 7W principle to be realised, as not only are the products delivered in the right quality, but they are also delivered in the right quantity at the

right time (Roncero, 2021). Packaging has many important functions and many different types of packaging have been developed to fulfil these functions. Each type of packaging is adapted to specific conditions and accepted norms and standards. Packaging can be divided according to (Mruk, 2001):

- the essential role they perform,
- the type of material from which the packaging is made,
- construction or shape,
- the possibility of using it in marketing.

There are many types of packaging, each with many different requirements[4]. Packaging is considered from the environmental aspect - biodegradable and non-biodegradable, from the marketing aspect - active (influencing demand) and passive, which do not influence consumer choices. In the distribution aspect, a distinction can be made, for example, between rented packaging or packaging included in the price of the goods (Driscoll, 2020). In logistics, a distinction is made between transportable, code-marked and non-code-marked packaging, stackable packaging and packaging where stacking is not possible. Lean Management is the choice for those companies that want to improve organisational agility and thus meet the conditions of today's ubiquitous and aggressive competition. 'The truth is that Lean Management is the most strategic approach you can use to transform your business' (Byrne, 2013). Although Lean Management has its origins in the manufacturing enterprise and was known as Lean Manufacturing, as its popularity grew, the name of the concept was transformed into Lean Management (Walentynowicz, 2013). Once improvements were achieved and consolidated in manufacturing areas, attempts were made to apply Lean principles and methods to other areas, or types of business, in order to gain a significant competitive advantage there too. Hence names such as Lean Office, Lean Development, Lean Administration, Lean Healthcare, Lean Service, Lean Logistics or Lean Packaging. These are developments of Lean Management and the application of its assumptions and instruments to the organisation and management of non-manufacturing areas in a manufacturing company or in other activities. Lean packaging aims to minimise waste and maximise efficiency. The idea is to use fewer resources and reduce costs at the same time. Lighter materials, recyclable options and a reduction in unnecessary components are used. This derives from the concept of lean manufacturing, which has its roots in the Toyota Production System. Lean packaging is an approach that draws heavily on the philosophy of lean manufacturing, or waste-free production. The key principles are[5,6] (Wandosell, 2021):

- Minimising waste: Using packaging that generates as little waste as possible. This can include reducing the use of plastic, using reusable packaging or biodegradable materials. Reducing waste means using packaging that is not only lighter but also easier to recycle.

[4] https://3lp.eu/rodzaje-opakowan-i-ich-funkcje-w-logistyce/
[5] https://lean.org.pl/transformacja-lean-schumacher-packaging/
[6] https://www.econocorp.com/packaging-efficiency-and-lean-manufacturing-strategies-for-success/

For example, many companies are switching to packaging made from biodegradable or compostable materials such as paper or cornstarch.

- Space optimisation: Designing packaging to maximise the use of space during transport, which reduces costs and CO2 emissions. Designing packaging that makes optimal use of space is key. Compact packaging helps maximise the use of available space in transport vehicles, which in turn reduces the number of transports needed. This in turn reduces CO2 emissions and transport-related costs.
- Innovation in materials: The use of modern materials that are lighter and more durable, which also helps to reduce costs and waste. Technological advances are making it possible to create new materials that are both lighter and stronger. An example is multilayer laminates, which combine the properties of several materials while offering greater product protection[7].
- Processes and technologies: the use of modern technologies and automation in the packaging process, which increases efficiency and quality. Automation and advanced technologies play a key role in lean packaging. The use of robotics and vision systems allows for more precise packaging of products, which reduces the risk of errors and increases process efficiency.

This approach is particularly important in the context of rising material costs and environmental awareness. Space optimisation is a key element of lean packaging, which focuses on maximising the use of available space when transporting and storing products. Here is how this can be achieved[8] (Galvan-Nina, 2022; Chruściel, 2022; Barbosa, 2024):

1. Compact packaging: Using packaging that perfectly fits the dimensions of the product, minimising empty spaces. For example, instead of using standard boxes, packaging adapted to the shape and size of the product can be used.
2. Modular packaging systems: Using packaging that can be easily stacked on top of each other, like blocks. This allows for efficient use of vertical space in warehouses and transport vehicles.
3. Design for optimisation: Engineers can use CAD tools to design packaging that maximises the use of space. These programmes create simulations that show how best to arrange products to minimise wasted space.
4. Multifunctional packaging: Packaging that is used not only for transport, but also for storing products without the need for additional containers. For example, containers that can be used both in transport and in shop as displays.
5. Using tape to bind the packaging: Instead of using larger boxes, products can be bound with tapes or film, allowing for more flexible placement in the transport space.

[7] https://www.packaging-gateway.com/features/lean-packaging-reduce-waste-increase-productivity/
[8] https://www.econocorp.com/packaging-efficiency-and-lean-manufacturing-strategies-for-success/

These techniques and strategies not only help to save space, but also contribute to lower transport and storage costs and reduce environmental impact.

Lean packaging is applicable across industries, adapting to the specific needs of each sector[9] (Urban, 2023; Womack, 2003; Nowak, 2018; Packaging Cans…, 2024). Here are some examples:

1. Food industry: food companies are using packaging that is lighter and easier to recycle. For example, some brands are switching to packaging made of biodegradable materials that not only protect products but also reduce environmental impact (Geueke, 2018).
2. Cosmetics industry: reusable and refillable (refillable) packaging is popular in the cosmetics industry. Customers can purchase products in refillable packaging, which reduces waste (Magnier, 2015).
3. E-commerce industry: online shops use packaging that is optimised for shipments. These are often modular packaging that can be adapted to different product sizes, minimising empty space in the parcel and reducing transport costs.
4. Electronics industry: electronics companies often use advanced packaging technologies to protect fragile products while reducing package size. For example, moulded cardboard inserts are used, which fit perfectly into the shape of the devices.
5. Pharmaceutical industry: In the pharmaceutical industry, product safety and protection are key. Lean packaging helps to optimise packaging processes, reducing material waste while ensuring adequate protection of drugs and supplements.

These examples show how versatile and effective solutions based on lean packaging principles can be (Innovations…, 2024). The tasks of lean packaging focus on several main objectives (Gaspersz, 2011):

- Waste minimisation: Reducing the amount of waste generated by packaging, both during production and after use of the product.
- Cost optimisation: Using materials and processes that are economically efficient, reducing packaging and logistics costs.
- Increasing efficiency: Improving packaging and transport processes to make them as efficient and less time-consuming as possible.
- Improving sustainability: Using environmentally friendly materials and introducing practices that aim to reduce the carbon footprint.
- Improving customer satisfaction: Creating packaging that is easy to use, aesthetically pleasing and functional, resulting in a better customer experience.

Lean packaging is an approach that aims to reduce waste and increase efficiency in packaging processes, while maintaining quality. Implementing lean principles in packaging can lead to significant cost savings, improved productivity and customer satisfaction.

[9] https://www.packaging-gateway.com/features/lean-packaging-reduce-waste-increase-productivity/

3. Analysis of the current packaging and possibilities of improving the packaging for the selected article

The analyzed company prefers pallet units with a uniform design, which is optimal throughout the supply chain and with dimensions of 1200x760 mm and 1140x800 mm, which are the optimal solution for both container sea transport and land transport. Additionally, the maximum height of pallet units is 1000 mm, as the entire supply chain is adapted to this height and any changes in this dimension negatively affect the loading capacity and transport efficiency. In order to better use the means of transport in terms of their cargo capacity, so-called filling solutions are used, i.e. a solution consisting in the full use of the cargo capacity of the means of transport by temporarily separating the cargo unit during transport. The analyzed company aims in its activities to eliminate pallet units that cannot be stacked, as they limit loading possibilities. The company has a three-level classification of pallet units based on their stackability:

1. Type 3 – stacking of up to 2 pallet units with a weight similar to the pallet unit, which is the base on which the next pallet units are placed (2 x the gross weight of the pallet unit).
2. Type 2 – stacking of up to 1 pallet unit with a weight similar to the pallet unit, which is the base on which the next pallet units and the top filler are placed (1.5 x the gross weight of the pallet unit).
3. Type 1 – stacking of any pallet unit and the top filler with a weight specified by the manufacturer-supplier (usually the gross weight of the stacked pallet unit is equal to the weight of the pallet unit on which the base is placed).

The preferred solution by the company is type II packaging, while the least desirable is type I and packaging that cannot be stacked. The maximum weight that can be stacked on a pallet unit should be specified by the manufacturer. In order for a pallet unit to be considered stackable, the following conditions must be met during testing:

a) no damage or permanent marks on the packaging or its parts (here understood as: individual packaging, collective packaging, pallet unit), on materials intended for handling and on the product itself,
b) no effects that lead to non-compliance with other requirements contained in the standards.

Pallet units that are not stackable must be marked in an appropriate manner. A special label must be placed on the left side of the pallet unit label. Information on the possibility of stacking pallet units is also very useful when arranging goods in the warehouse.

In addition to the most obvious requirement for packaging, i.e. that it has no impact on the price of the product, it should also be: convenient to transport, handy (i.e. it should be possible to remove it from the shelf, transport it to the car, bring it into the apartment, etc.), matched to the product so that it does not move inside the packaging (protective function) and easy to open.

The most commonly used packaging material is cardboard, while the company constantly strives to minimize the amount of packaging materials used. Technicians responsible for designing product packaging must take into account the following constraints stemming from the environment (expectations and capabilities of customers, suppliers, supply chain requirements) and the organization's internal environment (needs of the sales network):

a) no possibility of changing the product design (sometimes a change is permissible), even if it would have a positive impact on transport possibilities (filling rate, fewer transports, etc.),
b) the need to pack certain products in sets, even if packing them separately would be more beneficial (taking into account the customer's needs),
c) the need to adapt the dimensions of the packaging to the available handling equipment and means of transport,
d) the need to adjust the weight of consumer packaging so that the customer can remove the package from the shelf on their own,
e) taking into account the way a given item is displayed in the store (limited space for product presentation, product intended for a shelf or hanger, etc.).

Taking into account the above-mentioned limitations that packaging designers have to deal with, it can be assumed that the biggest challenge is packing large and heavy furniture. Here, the possibility of packing one item in several packages should be considered, which involves the need for appropriate exposure and clear communication in the store. The design of such packaging is a very complex process and requires many additional analyses and tests, which is why the selection of packaging materials and the creation of a packaging design for such large items usually begins at the product design stage. Unfortunately, it has been noticed that smaller items are not given as much attention, as by definition, many more of them can be transported in one transport than larger products. However, general cargo items have a very large share in the assortment of the analyzed company, and customers are more likely to buy home accessories than furniture. This relationship forces the need for constant availability of smaller items in the store. Well-chosen packaging will help in this case:

a) ensure the right amount of products in the store,
b) limit the number of transports necessary to transport a given number of items,
c) limit the number of pallets used,
d) reduce transport costs,
e) increase the margin on the product,
f) reduce the negative impact on the environment.

A good example of an item whose packaging contributes to the transport of significant amounts of air are food sealing clips. The product is sold in two different packages: 30 pieces per package and 10 pieces per package. A set of 30 clips contains: 20 clips 6 cm long and 10 clips 11 cm long. In a set of 10 clips, all have the same size - their length is 11 cm (Figure 1, 2). Regardless of the set, the clips are 1.6 cm wide and 2 cm thick (Table1).

Table 1.
Dimensions of food clips

Set	Clip height	Clip width	Clip thickness
Set of 30 pieces	11 cm i 6 cm	1,6 cm	2 cm
Set of 10 pieces	11 cm	1,6 cm	2 cm

Source: company materials and after Migdalska A.: Analysis of the packaging optimization process on the example of a selected product. Engineering thesis 2014 supervisor: J. Grabowska.

Figure 1. Food clips set of 10.

Source: www.ikea.pl

Figure 2. Packaging of a set of 30 clips.

Source: www.ikea.pl

Currently, the clips are packed in plastic bags, which also transport air unnecessarily. A bag containing a set of 30 clips has dimensions of 16x18x3 cm (height x width x depth), while a bag for a set of 10 clips has dimensions of 25x18x3 cm. The packaging method is shown in drawings number 3 (Figure 3).

Figure 3. Packaging of a set of 10 clips and 30 clips.
Source: www.ikea.pl

As for the set containing 30 clips, the level of air in the individual package was reduced to a minimum. As can be seen in the photo, the bag is almost completely filled with clips. However, the chaotic way in which they are arranged causes some problems with the arrangement of individual packages in the collective package, which contributes to a decrease in transport efficiency, i.e. the amount of goods transported in one transport. The difficulty here lies primarily in the different sizes of the clips. On the other hand, the package containing 10 clips of the same size is an example of wasting cargo space due to the significant level of air transported in the bag. Table 2 contains a set of data on the packaging solutions used for these products.

Table 2.
Data on packaging solutions for clips

Set	Dimensions of individual package	Dimensions of collective package	Number of individual packages in collective package	Dimensions of pallet unit	Number of individual packages on pallet unit
30 of clips	16x18x3 cm	38x38x29 cm	70 packaging	115x77x93 cm	840 packaging
10 of clips	25x18x3 cm	38x38x29 cm	95 packaging	115x77x93 cm	1 140 packaging

Source: company materials and after Migdalska A.: Analysis of the packaging optimization process on the example of a selected product. Engineering thesis 2014 supervisor: J. Grabowska.

In this paper, an improvement of the packaging of clips will be proposed, while maintaining the following assumptions:

a) the dimensions and appearance of the product remain unchanged,
b) the contents of the set do not change,
c) the possibility of changing the dimensions of the collective packaging,

d) the dimensions of the pallet unit cannot exceed the dimensions of the Euro pallet 120x80x100 cm,
e) the new packaging method cannot translate into an increase in the price of the product,
f) the new packaging method cannot be more expensive than the previous one.

In order to better illustrate the impact of the change in packaging on the company's results in various areas, the following data was adopted, which will help to better estimate the possible benefits of the proposed changes. For the purposes of this case study, it was assumed that the company:

a) sells about 10 million of each set of clips worldwide per year,
b) each year, for a set with 30 and 10 clips, respectively, it ships about 12 and 9 thousand pallets (a total of 21 thousand pallets),
c) the goods are transported in 40-foot containers, which can hold about 45 euro pallets loaded in two layers,
d) a total of 467 containers with clips must be shipped each year.

In order to identify the best packaging solution, several packaging scenarios were simulated for each set. The first and key change that was decided to be introduced was to replace the plastic bag with a heat-shrinkable film, which perfectly adapts to the shape of the product, reduces the level of air in the package, and additionally protects the products well during transport. The introduction of a new type of packaging also involves the need to properly arrange the clips in order to give them a form that allows the use of heat-shrinkable film.

For a set of 10 clips, two product packaging methods were taken into account - a single-layer package measuring 16x11x2 cm and a two-layer package measuring 8x11x4 cm. The adopted dimensions of the collective packaging are 55x40x33 cm, while the dimensions of the pallet unit are 110x80x100 cm. The unit consists of 3 layers of four cartons each (Figure 4).

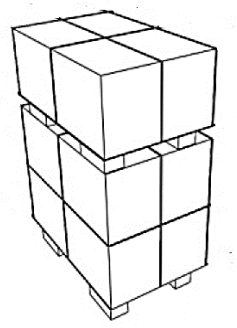

Figure 4. Design of a three-layer cargo unit with dimensions of 110x80x100.
Source: own study.

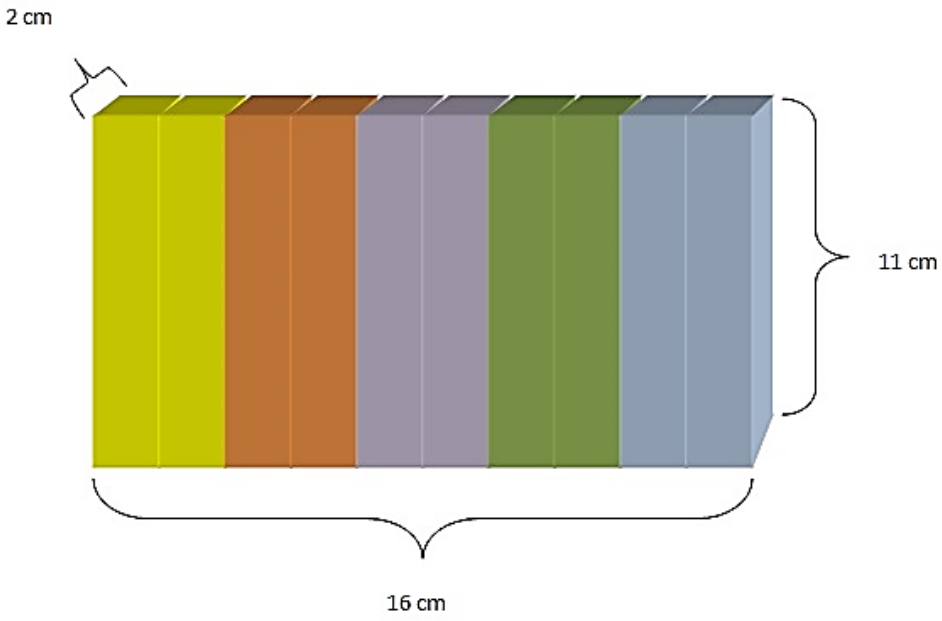

Figure 5. Single-layer clip arrangement – variant 1.

Source: own study.

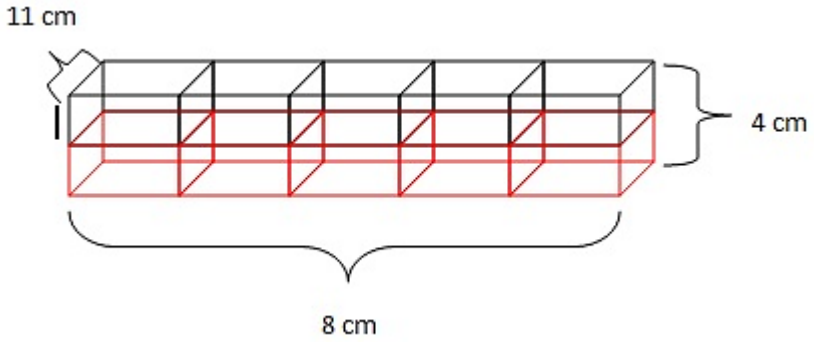

Figure 6. Two-layer arrangement of clips – variant 2.

Source: own study.

For variant 1, three different scenarios were tested (different arrangements of unit packages in the collective packaging). The first scenario (scenario 1.1.) assumed arranging the clips with the shorter side (11 cm) to the longer side of the collective packaging (55 cm). This allowed for the creation of two rows of 5 unit packages in each, leaving a space of 55x8 cm between these rows. The height of the packaging allowed for the arrangement of as many as 16 layers of unit packages. The space in the middle of the collective packaging was filled with an additional 40 unit packages by using the third dimension of the unit package, i.e. 2 cm of the side. Thanks to this solution, it was possible to fit 200 unit packages in the collective packaging. The second scenario (scenario 2.1.) assumed arranging the clips in such a way that the 2 cm side was adjacent to the 40 cm side of the collective packaging, and the 16 cm side was adjacent to the 55 cm side of the collective packaging. This solution turned out to be disadvantageous due to the inability to completely fill the space inside the box, even when using a different arrangement to fill the gaps. This solution allowed for packing 138 clip packages. Similar results were achieved in the third scenario (scenario 3.1.), which assumed arranging the 2 cm clips sideways

to the 55 cm side of the collective packaging. This scenario showed that a maximum of 192 individual packages could fit in the collective box. All scenarios proved that in order to fully use the capacity of the collective box, several arrangements of individual packages should be used, which allows for better filling of the packaging space. The first scenario was considered the most advantageous, which practically allowed for the elimination of transported air, while optimizing transport efficiency. Figure 7 shows a top view of the filled bulk packaging.

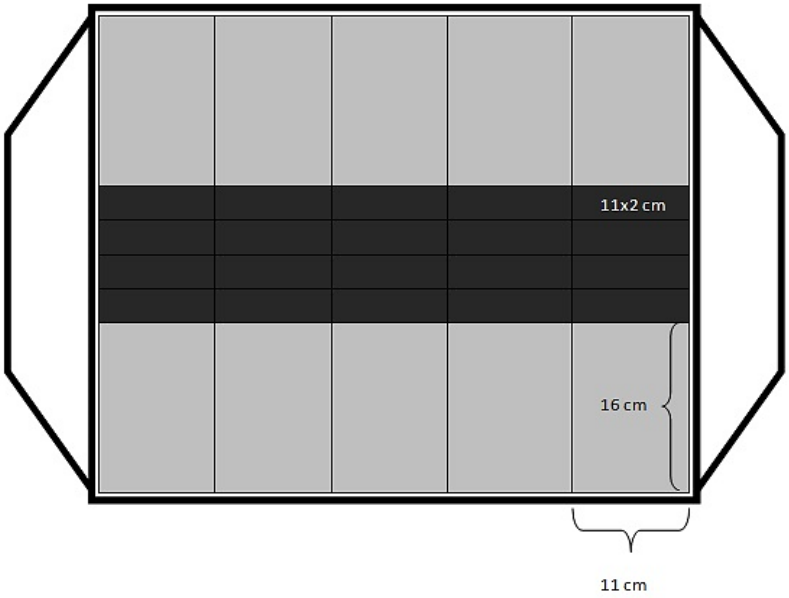

Figure 7. Scenario 1.1. – arrangement of clips packed in 10 pieces, single layer, in a collective package measuring 55x40x33 cm.

Source: own study.

The packages marked in light grey are arranged, as mentioned earlier, in 16 layers, while the dark grey packages are arranged in 2 layers. In total, the collective package holds 200 individual packages. Interesting observations were provided by conducting the next 3 simulations for variant 2. Arranging ten clips in 2 layers allowed for 200 individual packages to be placed in the collective package in as many as two scenarios. The first of them (scenario 1.2.) assumed the arrangement of 8 layers 4 centimetres thick and 25 individual packages in each. This effect was achieved by arranging the clips with an 8 cm side along the 40 cm side of the collective package. As a result, we obtained a result of 200 individual packages in the collective package. The second scenario (scenario 2.2) allowed the same result to be achieved by arranging the clips with a 4-centimeter side along a 40-centimeter side and an 11-centimeter side along a 55-centimeter side. In this arrangement, we obtained 4 layers 8 centimeters thick, each containing 50 individual packages. The last scenario (scenario 3.2), in which the clips were arranged with a 4-centimeter side along a 55-centimeter side of the carton, turned out to be completely unprofitable due to the fact that too much free space was left, which could not be filled in any way due to the incompatible dimensions of the individual packages. Of the two scenarios providing for the storage of 200 individual packages in

a collective package, scenario 1.2 is preferred, as the narrowest side (4 cm) of the individual package is arranged in such a way that the height of each layer in the collective package is translated. The individual packages are laid flat, which makes them more stable, and this method of packaging significantly speeds up and facilitates the process. In the case of a solution where the individual packages are laid vertically and the 4-centimeter side is the base, the packers have to spend additional time stabilizing the packages during loading - the narrow base causes the individual packages to tilt and are not tipped over. Below is a visualization of the preferred arrangement of clips packed in 10 pieces in two layers.

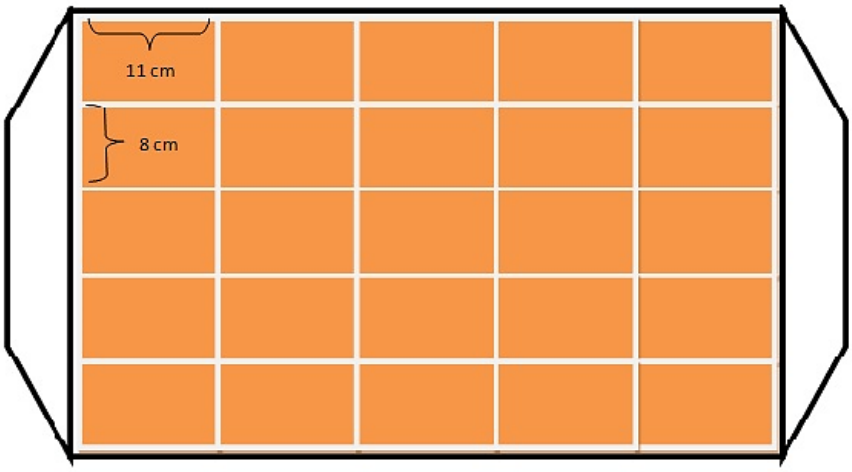

Figure 8. Scenario 1.2. – arrangement of clips packed in 10 pieces in two layers of 5 pieces each, in a collective package measuring 55x40x33 cm.

Source: own study.

The results of the presented simulations are summarized in the table below.

Table 3.
Summary of results obtained during simulation scenarios

	Scenarios					
	1.1.	2.1.	3.1.	1.2.	2.2.	3.2.
Criterion						
Number of unit packages	200	138	192	200	200	176
Number of layers	16 i 2	3	2	8	4	4
Method of arrangement***	11x16x2 cm	16x2x11	2x11x16 cm	11x8x4 cm	11x4x8 cm	4x11x8 cm
Unfilled space	no	yes	yes	no	no	yes

*** dimension placed along the longest side of the collective packaging (55 cm) x dimension placed along the shorter side of the collective packaging (40 cm) x dimension corresponding to the height of the collective packaging.

Source: own study.

Based on the data presented above, it can be stated that the optimal number of unit packages in a collective package with the dimensions we have adopted is 200 pieces. With a pallet unit made of 12 collective packages, the number of unit packages on a pallet is 2,400 pieces, which increases the number of consumer packages on a pallet unit by 1,260 pieces or 110%.

This change allows for a reduction in the number of pallets shipped worldwide annually from 9 to 4 thousand, and consequently the number of containers (transports) from 200 to 89 per year. Such a decrease in the number of pallets shipped and transports performed also translates into a reduction in CO2 emissions into the atmosphere, as well as a reduction in the amount of packaging materials used, which also has a positive impact on the natural environment.

Set of 30 clips – scenarios

Similar scenarios were generated and tested for a thirty-piece set of clips. Two alternative packaging options were considered again – single- and double-layer. Then, the impact of the arrangement of individual packages in the collective carton on the number of packages that could fit in it was examined. In this case, it was also decided to use heat-shrinkable film, as it is cheaper than plastic bags and, in addition, it minimizes the amount of air transported in the package, as it adheres perfectly to the product. Due to the specificity of the product, the collective package was widened by 1 cm and has dimensions of 56x40x33 cm. Two methods of packaging sets of 30 clips are visualized below.

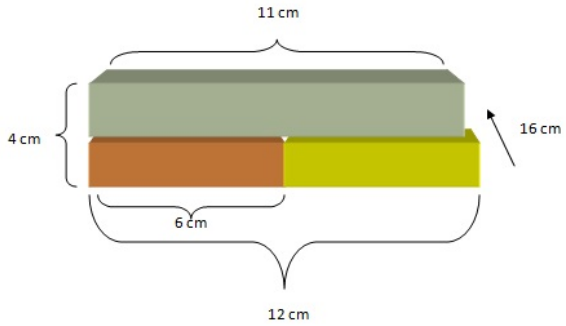

Figure 9. Two-layer arrangement of clips – variant 1.

Source: own study.

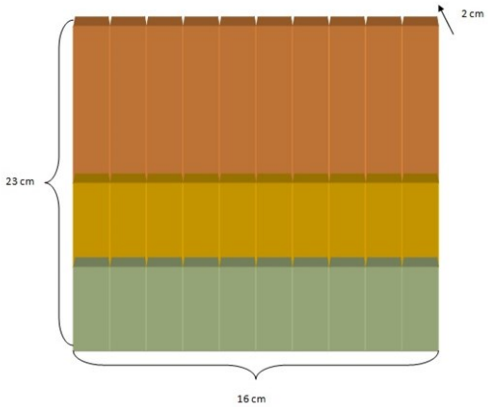

Figure 10. Single-layer arrangement of clips – variant 2.

Source: own study.

Four different scenarios were simulated for each variant. Possible ways of arranging consumer packages were tested, but none of the obtained results proved sufficiently satisfactory. Although using both variants it was possible to increase the number of consumer packages in collective packages, it was not possible to completely eliminate the transport of air in collective packages. Each scenario involved the need to leave a smaller or larger fragment of unused space inside the package. The best results for the first variant were obtained in the scenario that assumed:

a) arranging individual packages with a 4-cm side along the shorter side of the collective package (40 cm) and a 12-cm side along the longer side (50 cm),
b) filling the free space with 12 additional packages,
c) arranging two layers of individual packages.

As a result of this packaging method, the collective carton contained 92 individual packages, which is 22 more than with the current packaging method. The remaining scenarios allowed for the storage of 90, 88 and 62 pieces of individual packages in the collective packaging. The four scenarios carried out for the first variant yielded significantly worse results. The obtained results indicated the possibility of storing 93, 74 and 68 individual packages in the collective packaging. In this case, too, it was not possible to eliminate unnecessary air in the packages. Additionally, storing so many individual packages requires arranging them in several different ways in the collective packaging. This solution is disadvantageous due to the fact that it is much more labor-intensive and time-consuming. Slowing down the packaging or increasing its level of complexity generates additional costs, and the company tries to avoid such solutions. Below are visualizations of two packaging scenarios that allowed for the storage of the largest number of individual packages in the collective packaging. Unused space in the packaging is marked in black.

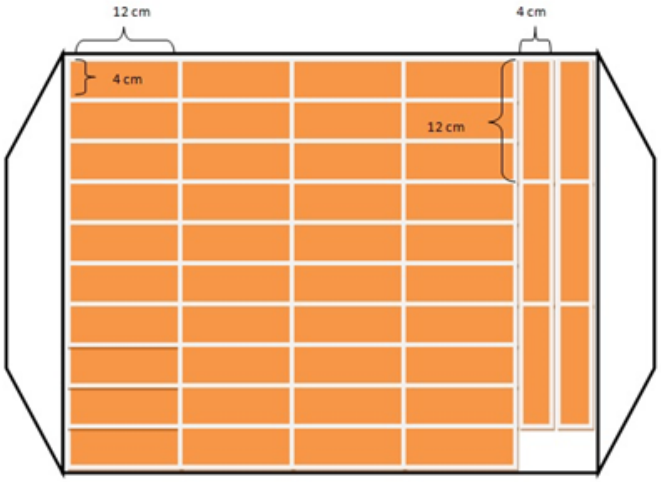

Figure 11. The best scenario among all simulated for variant 1.

Source: own study.

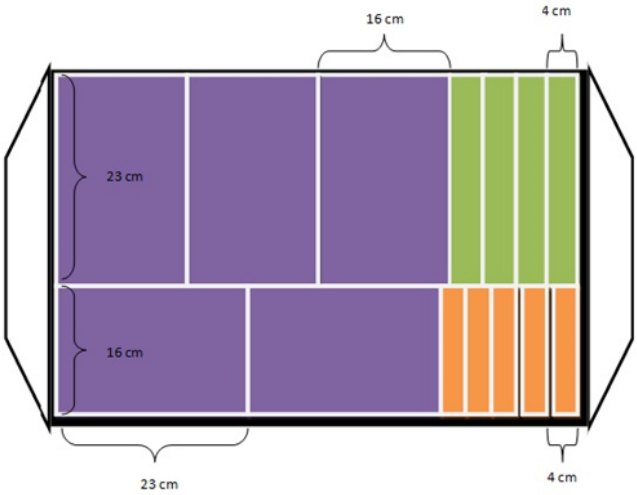

Figure 11. The best scenario among all simulated for variant 2.

Source: own study.

In the scenario, the unused space is 1 cm lost on the 40 cm wall of the collective packaging and the space at the location of the individual packages marked in orange in the drawing - it is not possible to create a second layer, and this results in a loss of 10 cm in the height of the packaging. Nevertheless, thanks to this solution, we can still pack 23 more individual packages than with the current packaging method. This translates into an increase in individual packages on a pallet from 840 to 1116 pieces, which is 33%. The solution reduces the number of pallets from 12 thousand to 9 thousand, and as a result, the number of necessary containers (transports) drops from 267 to 199 per year. Comparing the results of all simulations carried out for both products under consideration, it can be stated that while the solution for a set of 10 clips is satisfactory, the packaging for a set of 30 clips requires additional changes. The solution to the problem of transported air may be to select non-standard packaging and create a pallet unit with dimensions other than the Euro pallet. Since analyzed company often ships goods with non-standard dimensions and is willing to create pallet units with non-standard dimensions by using the so-called loading ledgy instead of wooden pallets, it is worth taking a closer look at these possibilities and adapting the packaging to the product. The problem is worth attention for several reasons:

a) product is a permanent element of the analyzed company assortment and is on the company's bestseller list,
b) it is a relatively light product, which allows it to be used as a top filler in mixed transports,
c) analyzed company has many similar products in its assortment, so developing an efficient packaging solution can translate into significantly greater benefits in the future.

For the BEVARA product, it is also worth considering the possibility of packaging the product in ready to sell - tear away packaging. Good arrangement of the product (i.e. flat) makes it stable enough to qualify as a product suitable for this packaging solution. This would allow for a reduction in packaging material, facilitate display in the shop, limit the manipulation

activities related to displaying goods in the shop, etc. However, the limitation here may be the expectations of the sales network, in which shop managers and persons designated for this purpose plan the shop space and organize space for individual items.

4. Conclusive remarks

Based on the analysis of the current packaging method for the product and the comparison of the results from the simulated scenarios, it can be clearly stated that packaging has a huge impact on the logistics costs in the company, mainly those related to transport, but also handling. Reducing the number of shipped containers from 200 to 89 (in the case of the best scenario for the article 10 clips) also reduces costs by approximately 110%. The example of a set of 10 clips shows how much simple solutions can change, and at the same time, this example shows that even giants in the field of logistics should still work on improving the solutions currently used. Small changes such as: replacing the packaging material, arranging the articles in a specific order in order to give the packaged product the right shape, appropriate arrangement in the collective packaging allows for a significant improvement in results in areas such as: transport efficiency, reducing the negative impact on the environment (lower consumption of packaging materials, fewer transports and therefore lower exhaust emissions, etc.), increase the margin on the product.

Ill-considered and carelessly designed packaging can lead to many losses, primarily financial, but also time and resources. That is why it is so important for suitably qualified technicians to work on the packaging already at the stage of designing the product itself. It is then possible to identify some potential problems and take appropriate steps to prevent them. What is more, the packaging design process cannot be limited to individual packaging. It is necessary to simultaneously plan a possible collective packaging and a pallet unit so that the packaging is as efficient as possible. Only such an approach can ensure the creation of packaging that is advantageous from the point of view of costs and logistics.

The packaging process itself should also be taken into account. The arrangement of products in the collective packaging should not be too complicated and allow for automatic/manual loading that does not require too many complicated movement activities, as well as eliminate the possibility of confusing the sequence of individual packages. The collective packaging can hold an exceptionally large number of individual packages, but when the packaging method is too complicated, it unnecessarily absorbs the time and energy of employees, and also increases the risk of errors, which are associated with double work and another loss of time. In summary, companies should constantly analyze the packaging solutions used by themselves and competitors and strive to exclude those that are harmful to the environment and cost-ineffective for the company itself. Even in the analyzed company assortment, you can find many products

that are still transported with unnecessary air, although a solution to get rid of it has long been developed. There are also often packages of too large dimensions, which the customer is not able to transport to the destination themselves, despite the fact that analyzed company focuses on the image of a self-service company. Other packaging-related problems, apart from not fully utilising the loading space, also include: inadequate securing of goods, poor labelling of packaging (incomplete information on the contents of the packaging on the label), half-empty trucks due to the inability to stack pallet units, negative impact on the environment, etc. Most of these problems lead to financial losses in the company, which is why it is so important to act preventively and design product packaging wisely, using the help of specialists, as this will allow you to achieve measurable benefits.

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