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PROFESSIONAL PAPER

Improving Supply Chain Efficiency Through Adequate Stacking of Bulk and Transport Packaging

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Abstract: The efficiency of logistics processes largely depends on the selection, sizing and stacking of aggregate and transport packaging. Properly organized packaging not only protects products but also directly affects the rationalization of space, the speed of manipulation and the reduction of costs in the supply chain. This paper analyzes the way in which standards and methods of stacking packaging units can improve operational efficiency. Through a theoretical review and analysis of practical examples, the role of palletization, modularity and optimal capacity utilization in the storage and transport process is discussed. The research confirms the hypothesis that adequate stacking of aggregate and transport packaging significantly reduces logistics costs and the time required for delivery, which directly contributes to improving supply chain performance.
Keywords: aggregate packaging, logistics, palletization, stacking, cost optimization.

LITERATURE REVIEW

The efficiency of the supply chain largely depends on the way packaging is designed and arranged within logistics units. Packaging is no longer just a protective wrapper, but an active and functional element of the logistics system, which affects costs, transport time, handling and storage. Modern packaging technologies strive to provide the highest possible process efficiency and product protection at minimal cost (Rodrigues & Han, 2003).

According to Han, Rodrigues and Han (2005), intelligent packaging must include functions that provide logistical support, such as storage condition indicators, integrated stability markings and optimized stacking systems. They point out that stacking of bulk and transport packaging can be viewed as a structured technical operation, which must be based on an analysis of stability, economy and space utilization.

Lim (2011) believes that packaging is becoming one of the essential resources of supply chain management, since it actively participates in the flow of goods, provides feedback and enables real-time system adaptation. In this context, the logistical potential of packaging must be included already in the design and simulation phase, and not only in the implementation phase.

Stilwell (1991) warns that improperly designed packaging not only leads to increased costs, but also to environmental consequences, including excessive material consumption and unnecessary burden on disposal systems. For this reason, packaging design must be accompanied by sustainability criteria, standardization, and software control of the composition.

Based on the above theoretical foundations, this paper aims to show how adequate stacking of aggregate and transport packaging can contribute to improving the overall efficiency of the supply chain. The research relies on simulations in the CAPE PACK software, and the analysis of the results is aimed at confirming the hypothesis that rational stacking design reduces the costs and time of logistics processes.

INTRODUCTION

Packaging plays a central role in the modern supply chain, where it no longer serves only as product protection, but has become a key factor in efficiency, cost rationalization and optimal use of logistics resources. Modern market needs have led to the design and functionality of packaging being viewed as an integral part of the logistics system, especially when it comes to bulk

and transport packaging, which enables the organized handling and storage of larger quantities of goods in the loading, transport and distribution processes.

According to studies dealing with logistics engineering, optimally designed aggregate and transport packaging can contribute to reducing operating costs and time losses, and improve overall stability, safety and speed of delivery. Insufficiently adjusted dimensions, irregular shape and poor stacking of packaging units often lead to insufficient utilization of pallet, truck or warehouse capacity, which results in a higher number of transport rounds, higher energy consumption, increased handling time and additional financial costs.

Solutions are increasingly found in software support, with the CAPE PACK program being the most prominent in practice , designed for dimensioning, calculating and simulating the stacking of packaging within logistics units. By using this tool, it is possible to simulate the arrangement of packaging on pallets in advance, use the space in the truck and adapt the dimensions of the packaging to a specific logistics scenario. The paper presents three simulated cases, where the impact of different stacking methods on the total number of required pallets, load stability and the degree of transport utilization was analyzed. The results obtained indicate significant space savings and a reduction in logistical losses, which confirms the justification of a systematic approach to packaging design.

Starting from these assumptions, the aim of the paper is to show how adequate stacking of aggregate and transport packaging contributes to improving the efficiency of the supply chain. The research is based on the hypothesis that proper dimensioning and planned stacking of packaging units leads to a reduction in costs and time required for logistics operations. Practical examples, supported by simulation in the CAPE PACK program, provide a comprehensive insight into the importance of proper packaging organization in terms of overall supply efficiency.

Modern trends in logistics and packaging impose the need for the application of digital tools such as simulation software and multi-criteria decision-making models. Digitalization of packaging processes and optimization of packaging layout on pallets are becoming key elements for achieving efficiency in the supply chain.

In order to verify the hypothesis and apply the theoretical knowledge in practice, the paper analyzes the specific case of a company from Derventa that produces ketchup. Using the CAPE PACK simulation software, various packaging stacking configurations were examined, with the aim of determining the efficient layout in accordance with the characteristics of the product and the company's logistics resources. The research was conducted on the example of a company from Derventa that produces ketchup, where the methodological approach included the simulation of various layouts of bulk and transport packaging in the CAPE PACK software, in order to determine the efficient solution in terms of logistics capacity utilization.

Functions of bulk and transport packaging

Bulk and transport packaging represent an intermediate layer between primary packaging (which is in direct contact with the product) and the logistic units that are transported and stored. Their main function is to group multiple primary packaging units into units suitable for manipulation, loading, unloading and transport. In addition to physical protection, these types of packaging must provide stability during movement, efficient stacking within warehouses and means of transport, as well as reducing the number of individual operations during handling of goods.

Bulk packaging most often consists of cardboard boxes or crates in which multiple units of the same product are packed, resulting in packages that are easier to count, store, and transport. Transport packaging is a higher level, which includes grouping multiple bulk packages on a pallet, container, or other means of transport, with the aim of enabling rational use of space and reducing the possibility of damage during transport.

Proper sizing and stacking of bulk and transport packaging allows for full use of pallet space, load stability, and easy loading and unloading activities. Otherwise, incorrect dimensions and inappropriate package combinations lead to wasted space, increased pallet count, less stability, and higher distribution costs.

Additionally, one of the important goals of designing collective packaging is compatibility with means of transport, which is achieved through a modular design approach - the dimensions of collective packaging are adapted to the standard dimensions of Euro pallets and freight vehicles, in order to avoid unnecessary empty space. In this context, logistics packaging also becomes a strategic resource, as it allows for the reduction of costs per unit of product at all stages of movement through the supply chain.

METHODOLOGY

The research in this paper is focused on analyzing the impact of stacking of bulk and transport packaging on supply chain efficiency. The initial hypothesis is:

- Adequate stacking of bulk and transport packaging contributes to the optimization of costs and time in the logistics process.
- The goal was to determine to what extent the application of modern stacking methods, with the support of software simulation, can achieve better utilization of pallet and transport space, reduce the number of necessary manipulations, and reduce logistics costs.

Stacking methods and application of CAPE PACK software

The design of the layout of the aggregate and transport packaging is carried out using specialized software CAPE PACK, which allows the simulation of the package configuration according to input parameters such as dimensions, weight, number of boxes and transport restrictions. Using this tool, it is possible to visually and numerically compare multiple layouts and select the one that reduces costs and increases stability to the greatest extent.

As Esko (2015) points out, CAPE PACK provides the ability to create stacking models in several steps: defining primary packaging, generating layer layouts , simulating transportation, and analyzing key logistics indicators. Such an approach allows for optimal decisions to be made already at the packaging design stage.

The modular stacking methodology as an element of logistics cost management has also been confirmed in studies such as Han et al. (2005), which emphasize that packaging optimization must be based on digital simulation and transparency and sustainability criteria.

CAPE PACK enables the design and analysis of packaging systems by entering parameters related to primary packaging, such as length, width, height and weight, as well as the number of units per aggregate package. Based on this input data, the software calculates different possibilities for arranging boxes per layer and layers per pallet. The data input also includes restrictions related to maximum pallet height, cargo weight, handling method and logistics standards. An example of such an input is shown in ***Figure 1.***

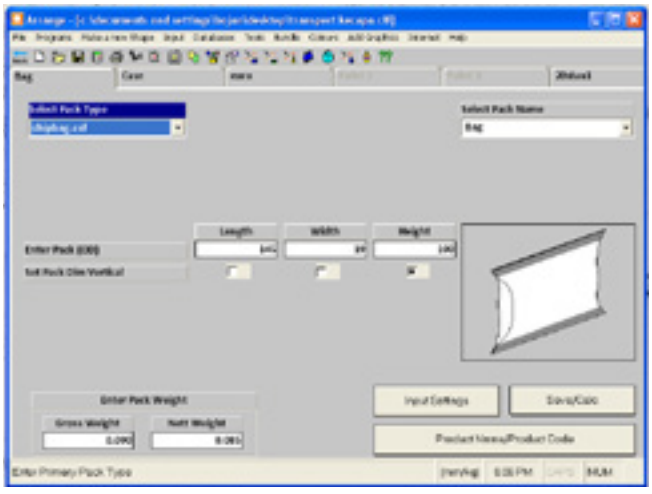

Figure 1. Data Entry for Primary Packaging

A company from Derventa produces and packages ketchup, and the problem arises from the need to deliver ketchup. Primary packaging is a bag containing ketchup. Secondary packaging serves to protect the primary packaging and, in addition, to perform other distribution functions of the packaging business. Secondary packaging is a cardboard box in which ketchup bags are placed. The company from Derventa uses a standard EURO 4 pallet. The boxes are placed manually on the pallet according to a predetermined layout.

The total length of the bag is 145 mm, the height is 100 mm, the thickness is 19-20 mm and the weight is 90 grams. The cardboard box used as collective packaging should contain 20 pieces of product already packed in primary packaging. The length of the cardboard box is 400 mm, the width is 140 mm, and the height is 105 mm. The standard EURO pallet has dimensions of 800x1200x150 mm, weighing 25 kg. The dimensions of the truck are 6500x2320x2350 mm.

Figure 2 shows a planar arrangement of box stacking, with boxes marked in yellow and unused pallet area in green. After calculation, a large amount of unused pallet area is observed, reaching as much as 12.5% of the pallet area. Here, the need arises to consider rearranging the arrangement of boxes in order to improve the pallet area utilization.

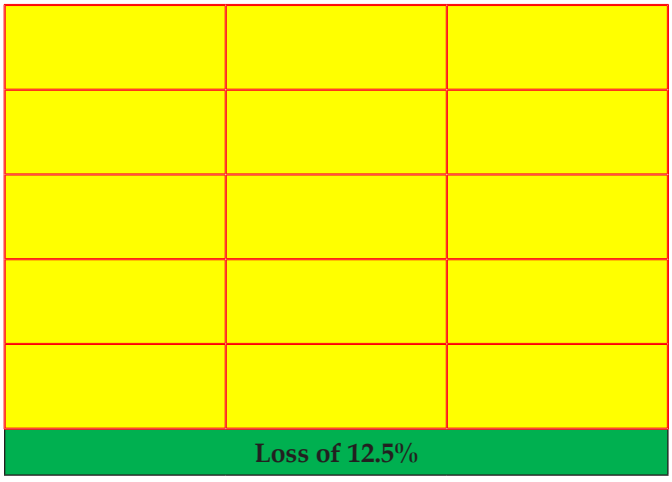

Figure 2. Box Laying Schedule on Pallet

After the program has been launched and the Arrange/ Design group selected, it is time to enter the necessary parameters to define the primary packaging, in this case a ketchup bag. The dimensions are indicated in the window: length, width and height. The bag dimensions are 145x100x20, and the mass is 0.09 kg. A standard EURO pallet with dimensions of 1200x800x150 mm, a maximum load capacity of 2000 kg, and a maximum load height of 1650 mm was selected.

After defining the input parameters, CAPE PACK automatically generates several different models of the arrangement of aggregate packaging on a pallet. Each of these models provides information on the number of boxes per layer, the number of layers per pallet, the total height and volume of the cargo, as well as the percentage of pallet area utilization. The resulting stacking arrangements and the arrangement of packaging are shown in the following figures.

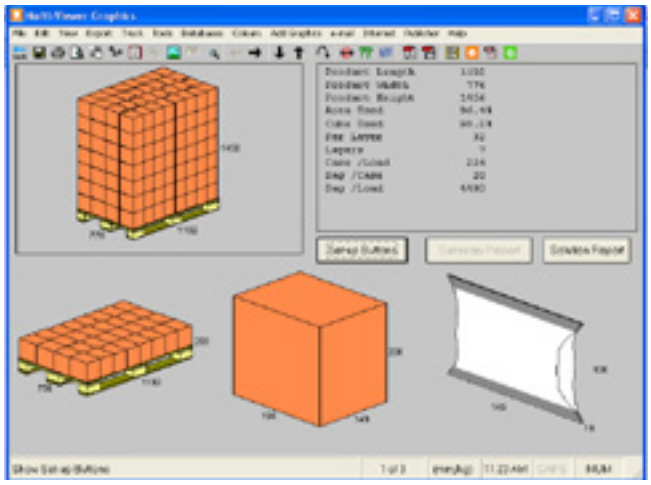

Figure 3. Packaging Arrangement for the 1st Case Found

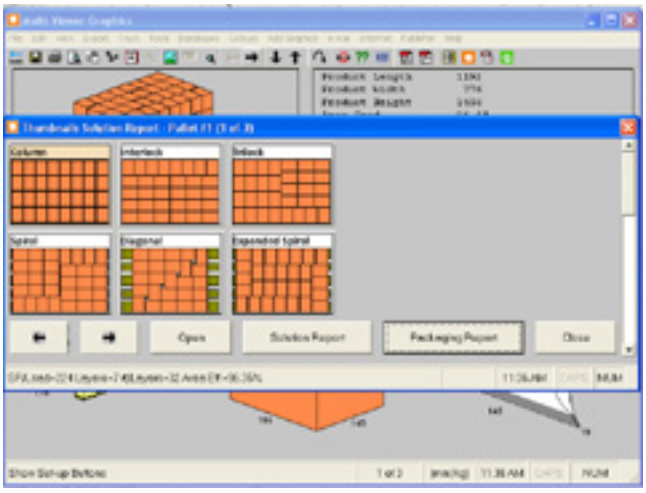

Figure 4. Laying Methods for the 1st Case Proposed

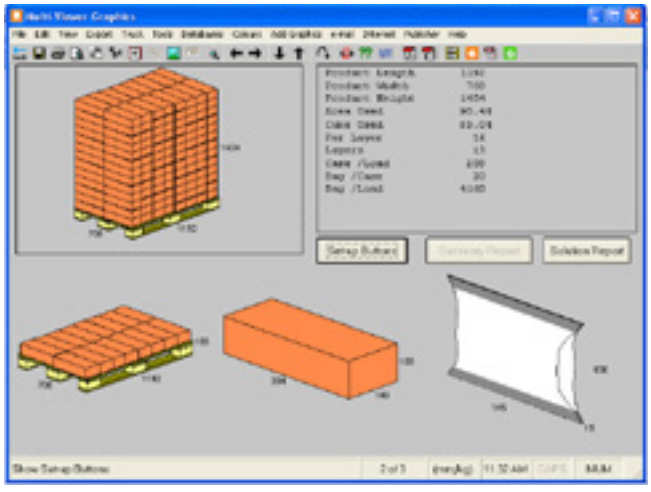

Figure 5. Laying Methods for the Proposed 2nd Case

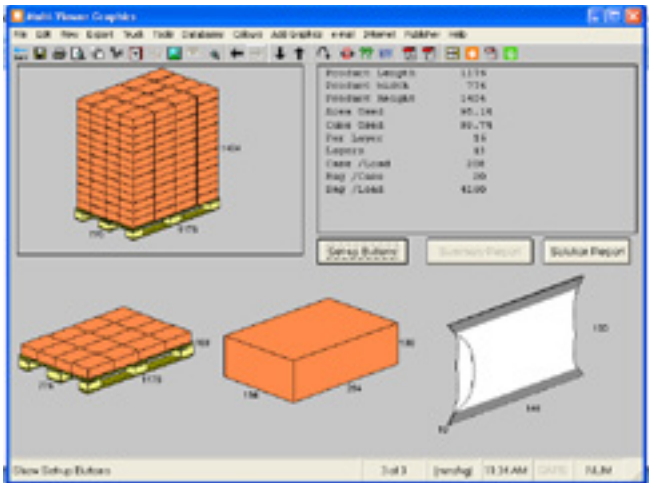

Figure 6. Packaging Arrangement for the 3rd Case Offered

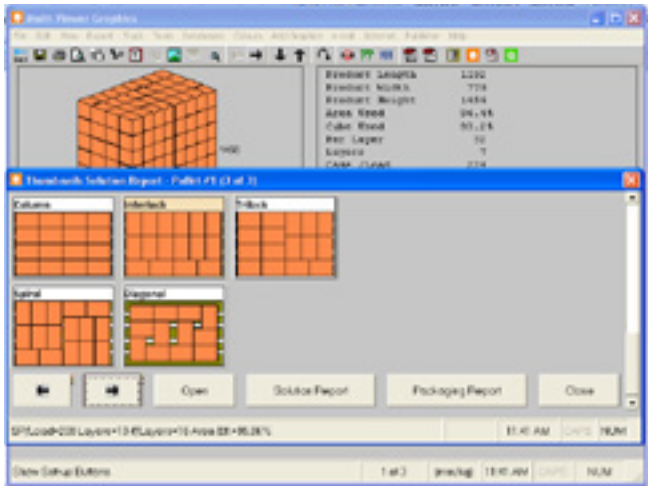

Figure 7. Laying Methods for the Proposed 3rd Case

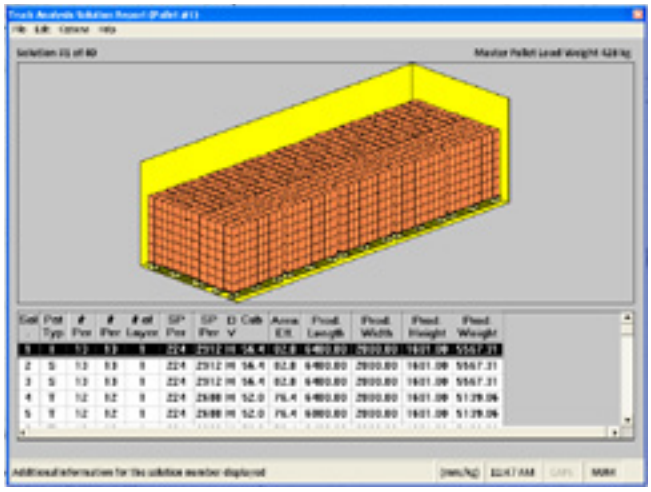

Figure 8. Pallet Arrangement in the Truck For Case 1

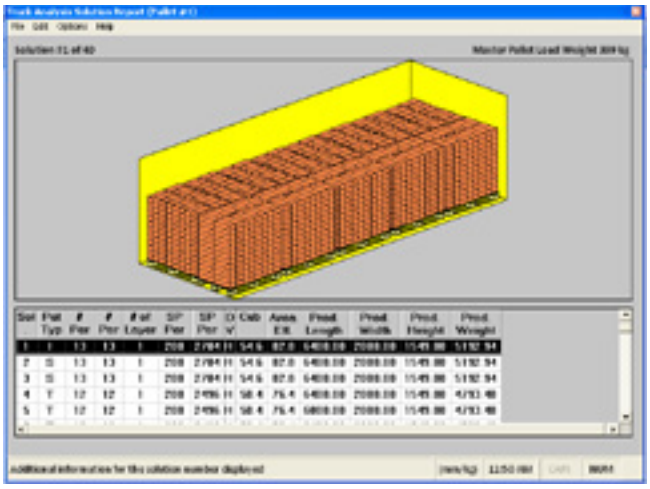

Figure 9. Pallet Arrangement in the Truck For Case 2

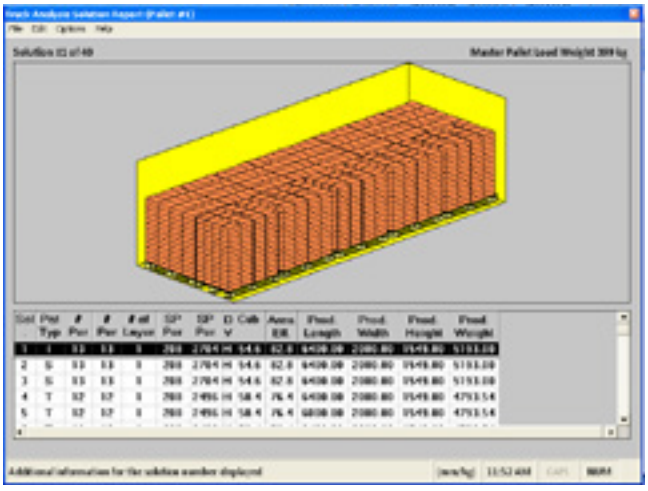

Figure 10. Pallet Arrangement in the Truck For Case 3

The results obtained are then compared and analyzed with the aim of selecting the most favorable variant. During the analysis, key criteria are observed: total pallet occupancy, cargo stability, logistical profitability and the number of pallets required to transport the same quantity of goods. The overall simulation results are shown in ***Table 1.*** The table presents parameters such as the number of boxes per pallet, number of layers, load height, percentage utilization of pallet area and the total number of pallets required for each simulated variant.

Table 1. Simulation Results

	Solution 1	Solution 2	Solution 3
Used pallet area, %	96.4	95.4	95.1
Used pallet volume, %	93.5	89.3	89.0
Products on a pallet, com	4480	4160	4160
Used truck area, %	82.8	82.8	82.8
Used truck volume, %	56.6	54.7	54.7
Pallet load capacity, kg	428	399	399

Based on a detailed analysis from the table, the model that shows the best ratio between utilization and stability was selected — that is, the model in which the number of boxes on the pallet is maximum, and stability and logistical functionality meet the criteria.

The simulation results show that even the smallest changes in the dimensions of the collective packaging or the way it is stacked can have a significant impact on the overall logistics efficiency. Software analysis, which allows visualization, comparison and measurable assessment of each layout, provides the basis for rational decision-making already at the packaging design stage. This leads to better space utilization, a reduction in the number of transport units, fewer manipulation operations and, ultimately, significant savings in distribution costs.

DISCUSSION OF RESULTS

The way in which bulk and transport packaging is organized within a logistics system has a significant impact on the overall efficiency of supply. Viewed through the prism of the arrangement of boxes on a pallet and in transport vehicles, rational stacking directly affects the number of pallets required, space utilization, load stability and the number of handling operations.

The simulation results, already presented in Table 1 and Figure 3, showed that different stacking models lead to significant differences in capacity utilization. The most optimal model achieves a pallet fill rate of more than 95%, which leads to a reduction in the number of pallets needed for the same volume of products. This means less transport, less fuel, less labor and shorter logistics processing times, but also less storage space.

In addition to reducing costs, the results also indicate a reduction in cargo processing time – whether loading, unloading or storage. Increased cargo stability, achieved by precise box arrangement, also reduces the risk of damage, which further reduces indirect costs in the supply chain. Through better planning and simulation, the need for excess protective material and improvised solutions in the transport phase is eliminated.

Applying a simulation approach, such as CAPE PACK, allows logistics managers to determine the most economical stacking model before production or shipment. This allows decisions to be made based on data, rather than assumptions or habit, which significantly improves the quality and reliability of logistics operations.

CONCLUSION

This paper analyzes the impact of stacking of bulk and transport packaging on costs and time in the supply chain, with the aim of determining to what extent a rationally designed layout can contribute to logistics efficiency. By applying simulation in the CAPE PACK software

and comparing multiple stacking scenarios, data was obtained showing that proper dimensioning and configuration of packaging leads to a significant reduction in the number of pallets, greater utilization of space capacities and shorter duration of logistics operations.

Key results confirmed that the optimal arrangement of packaging units allows pallet fill rates above 95%, which directly reduces transport and handling requirements. In this way, the overall efficiency of the system is improved, and the costs associated with manipulation, storage and transport are reduced. In addition, the stability of the load increases transport safety and reduces the risk of product damage.

These findings enabled the verification of the initial hypothesis that adequate stacking of aggregate and transport packaging contributes to the optimization of costs and time in the logistics process . The confirmation of the hypothesis is based on quantitative and visual simulation results, as well as on the theoretical foundations of modern approaches in logistics and packaging design.

The paper highlights the need to view packaging as an integral part of supply chain management, not just as a means of protecting products. The application of simulation and optimization tools in the early design phase is a key step towards a more efficient, cheaper and more sustainable logistics system.

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