ANNALS of Faculty Engineering Hunedoara – International Journal of Engineering
Tome XX [2022] | Fascicule 1 [February]

[1.]Adrienn BOLDIZSÁR, [1.]Erika TÖRÖK, [1.]Attila PÁSZTOR

ANALYSIS OF PACKAGING TECHNOLOGY SOLUTIONS FOR TODAY'S INDUSTRIAL COMPANIES IN HUNGARY

[1.] John Von Neumann University, GAMF Faculty of Engineering and Computer Science, Department of Information Technology, Kecskemet, HUNGARY

Abstract: The present research deals with developing the Industrial 4.0 modular industrial packaging machine for integrated data analysis and optimization and error analysis based on artificial intelligence. It aims to explore the typical packaging methods, customs, and needs of the industrial market companies operating in Hungary. A modular final packaging technology will be developed in the long run, enabling fast customer service and flexible adaptation to customer needs. Packaging technology, as an industry, is an essential component of production in terms of both environmental and economic impacts. Combined with Industry 4.0 and modularity, it offers a new area of research that can offer a solution to the logistics and production challenges of the future in this field. Background research was carried out as a first step, including market research. Based on the questionnaire survey data, the packaging technical characteristics and needs of 58 Hungarian companies were processed. Preliminary from the research, we expected that companies are open to the potential applicability of Industry 4.0 in the field of packaging and pay close attention to this area. In addition, we used the Chi-square test to determine whether there is a correlation between the type of packaging used and the type of packaging in terms of protection against external influences.

Keywords: packaging technology, industrial company, statistical analysis, universal packaging machine, Industry 4.0, Chi-square test

1. INTRODUCTION

In increasingly global, volatile markets, as highlighted by the pandemic situation since 2020, companies need to support efforts to improve the efficiency and sustainability of their supply chains in more competitive markets. The design of appropriate packaging during production is critical in achieving this goal, with large companies focusing on the efficient, sustainable integration of packaging, product, and supply chain systems. [8] The research explores the typical packaging methods, habits and needs among market partners and companies. As a first step, a research framework has been set up to assess how this will be assessed (Figure 1).

The figure shows that the data were generated using a questionnaire query and analyzed using statistical tools. The following publications related to the research area were examined.

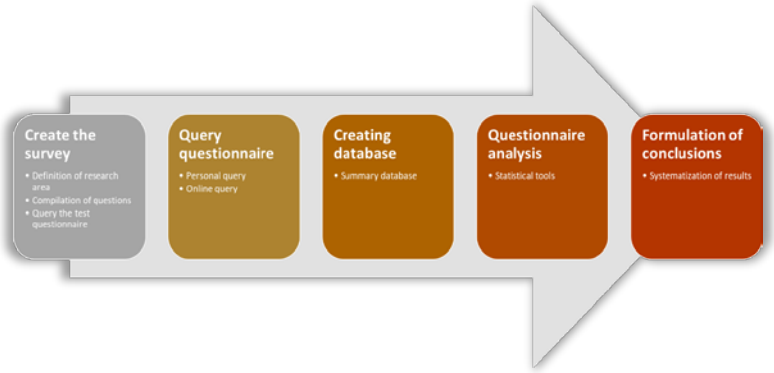

Figure 1. Presentation of the research framework [Source: own editing]

2. LITERATURE REVIEW

Packaging has always been a part of our lives, from the most straightforward tools used in prehistoric hunting (such as the original plant-wrapping leaves used to protect meat) to the special-purpose packaging we use today. It is no coincidence that much of the research is mainly related to food packaging, which has undergone tremendous development over the past 200 years. It primarily began with the emergence of canning, and from the end of the 20th century, it gradually emerged as a separate discipline among the research topics. [6] From the point of view of packaging research, we cannot say about the associated principles of waste management, which have become one of the crucial drivers of the whole industry. An important buzzword in all this is the creation of green logistics and supply chains, which require the joint efforts of governments, logistics businesses, and consumers. [7]

Packaging can be interpreted in two ways. It means, on the one hand, the operations that ensure the protection of the product during storage, transport and distribution, and, on the other hand, the unity of the product and the protective cover created as a result of the former activity, i.e. the product produced during the operation. Its primary task is to preserve the quantity and condition of the goods and, in the case of perishable goods, their quality from production to the intended use throughout the entire distribution chain. However, the packaging must provide two-way protection and protect the environment from the product's harmful effects, for example, in the case of dangerous goods. [4] Packaging plays a vital role in marketing and purchasing. It contributes significantly to the success of a product, and it connects with customers. It is often the only clue to the purchase

decision. With this feature, packaging as a cost factor can become a significant added value. In some cases, it is more critical than the packaged product itself. The information on the packaging protects consumers and helps identify goods during transport and storage. [4] Table 1 summarizes the latest results in terms of packaging technology research.

Table 1. Summary of relevant international research literature in terms of packaging technology [Source: own editing]

Citation	Viewpoint	Scope	Parameters examined
[12]	Future research opportunities for reusable packaging	Review - logistics systems	Environmental, economic costs; logistics system design; operation management.
[1]	Impact of food packaging on the environment	The food industry, microbiology	Materials, food product developments, properties.
[2]	Sustainability, recyclability	Textile industry	Substratability of textiles instead of paper and plastics as solid coverings.
[5]	Innovative packaging technology solutions	General packaging technology solutions	Plasma coating, permeability, safety technology.
[3]	Overview of packaging materials and technologies	Dairy products	Overview of packaging materials, technologies, and application for liquid milk, fermented milk, cheese, butter, and dry milk powder.
[9]	New food packaging technologies	Food industry	Innovative food packaging techniques; the mode of action of the preservative; efficacy and suitability in different types of foods.
[16]	Green logistics with route optimization	Application of eco-packages	Cost of routes, search for the shortest route, sensitivity analysis in the life cycle of eco-packages.
[11]	Computer systems used in the logistics and post-logistics stages of the food packaging life cycle	Food industry	Development possibilities of computer systems.
[15]	New packaging technologies for the 21st century	Meat packaging	Packaging materials and technologies; meat industry solutions.
[10]	The intelligent packaging technologies in the food sector	Food industry	The basic principles and market applications of intelligent systems; legal, economic and consumers' behaviour research.
[14]	Industrial packaging and its impact on sustainability and circular economy	Industrial packaging	Supply chain efficiency, environmental impact, development process, regulatory compliance, economic and environmental research.

It is also clear from a review of the literature and the table that research on packaging technology focuses mainly on recycling and future materials. Within this, the most popular topic in the food industry. At the same time, it is clear that it has become an essential part of the supply chain and the planning and management of industrial companies, both in terms of sustainability and cost.

After reviewing the literature, the answer was sought to find out how the ideas and solutions of industrial companies related to packaging technology in Hungary are currently developing, starting from all these trends and guidelines. For this, a questionnaire was created, the methodological description of which can be found in the third chapter. In the fourth chapter, the questionnaire results were summarized, while in the fifth chapter, the correlations between the questions were explored using statistical tools. All this aims to map the market needs and the possible connections among the industrial companies, thus providing an opportunity to designate new research areas in the creation of packaging technology machines.

Figure 2. Territorial delimitation of packaging technology from the point of view of research [Source: own editing]

3. METHODOLOGY

The first step was to create a questionnaire. After reviewing the questionnaire questions and preparing the literature, it was determined which areas we would like to delimit with the questions regarding packaging technology and the content of the questions. The parameters specific to the packaging technique were covered following a literature review, as shown in Figure 2.

It can also be seen in Figure 2 that five large territorial sub-units were selected, with the help of which information was collected from the companies as a first step; this protection against external influences; capture into the appropriate unit; protecting the environment from the effects of the product; sales promotion; and

what solutions are used by today's industrial companies in Hungary to facilitate the usability of the product. The questions were formulated about these five sub-areas, and regarding the structure of the questions, closed and open questions were used, including half-choice questions and the possibility to answer independently. A database was created from the collected responses and then analyzed using statistical tools.

During the compilation of the questionnaire, the goal was to perform a correlation analysis between the two questions based on the answers received. The answer was sought as to whether, when a new product is added to a company's product range, it represents a new packaging material or changes the choice of packaging material as a function of protection against external influences, as these have emerged as the most critical factors in the literature. Correlations were explored using a χ^2-square test and cross-tabulation analysis. [14] The test was created by performing the following five steps:

- Formulating a hypothesis for the given population (two questions selected from the questionnaire) (null and alternative).
- Calculate the frequency of events below zero. For this, the responses to the request form were binary colourized (0 or 1).
- Record the number of items observed.
- Calculate and summarize the difference between the observed and expected numbers. The difference gives the calculated value of the χ2 test.
- The test statistics will be compared with the critical points of the χ^2 distribution, and a null hypothesis will be decided.

It is important to note that the questionnaire created also had a group of questions related to IT. However, in the present study, this part is not analyzed. Only the analysis of packaging technology in the logistic sense is presented. The following section provides an analysis of the answers to the packaging technical questions of the questionnaire.

4. PRESENTATION OF THE RESULTS OF THE QUESTIONNAIRE

The questionnaire was interviewed from 58 companies operating in Hungary in the spring of 2021. The response was voluntary and anonymous. Companies were categorized in terms of which sector they operate in the industry (Figure 3).

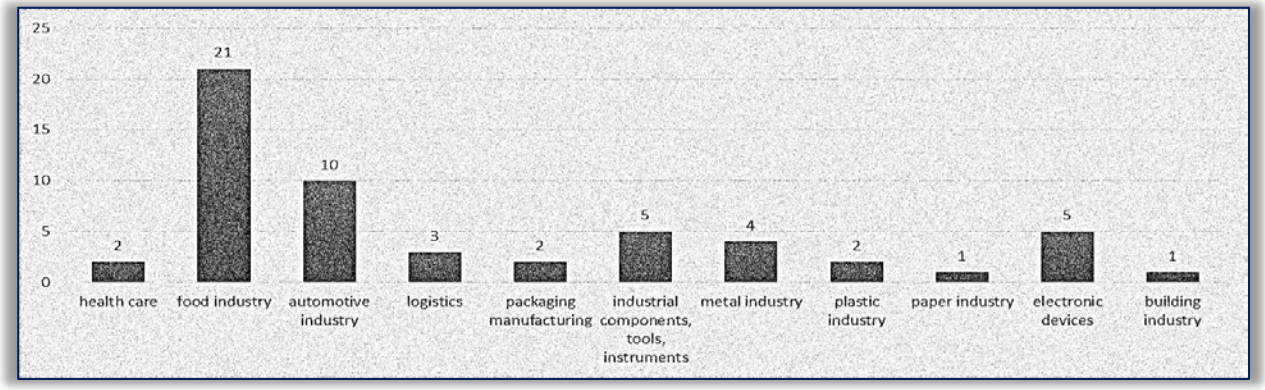

Figure 3. Profiles of the surveyed companies [Source: own editing]

As can be seen from the literature search, most of the companies in the food industry are involved in packaging technology, with almost a third of the companies answering questions from this industry. The answers to the questions are categorized according to the five areas delimited by the research methodology.

— Protection against external influences, protection of the environment from the effects of the product

Protection against external influences and the protection of the environment three issues were listed here. The first thing to look for was whether the handling of products marketed by companies required any special rules. About special regulations, a distinction was made between food, hazardous substances, the other category in which respondents were free to answer and a negative answer (Figure 4).

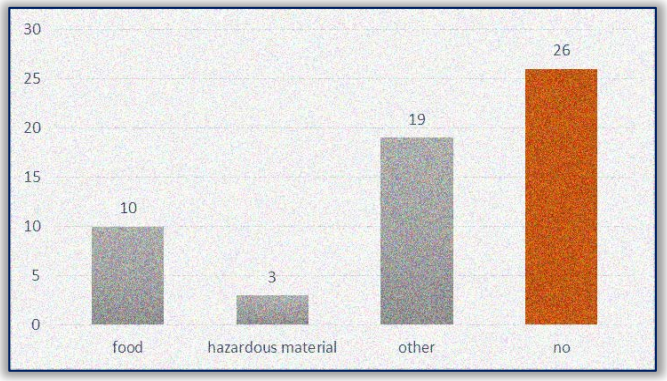

Figure 4. Product categories that require special rules [Source: own editing]

Nearly half of the companies surveyed do not have products in their portfolios subject to special rules. Comparing Figures 3 and 4, it can be seen that while 21 companies have a food industry profile, it was indicated in 10 cases for categories that work with food subject to special rules. One reason for this is that some have chosen the 'No' category here, and there are those who have wanted to indicate the type of food they sell (e.g. mineral water) in other ways. Products such as automotive parts and pharmaceutical products with special packaging rules have appeared in the 'Other' category. We specifically wanted to assess the external influences against which companies supply their products with packaging using the following question. There were several possible answers to some questions, so the number of answers marked by the companies is also shown separately (Figures 5/a and b).

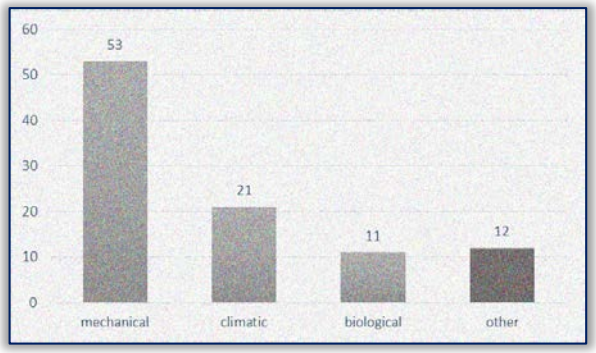

Figure 5/a. Protection against external influences by category [Source: own editing]

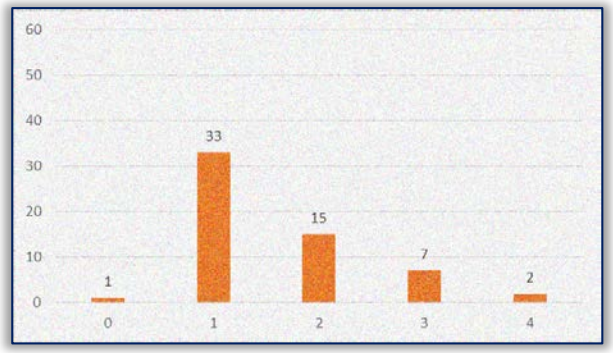

Figure 5/b. Number of responses regarding externalities [Source: own editing]

The diagram clearly shows that packaging is mainly used against mechanical effects. Almost all companies have indicated this possibility (53/58). Other categories include electrostatic protection, protection against dust and external contaminants (water and airtightness), strictly for mechanical effects, and protection against chemical effects (rust). About two-fifths of the companies surveyed use packaging against multiple effects. In terms of packaging materials, paper can be the most popular, but the use of plastic lags behind (Figures 6/a and b).

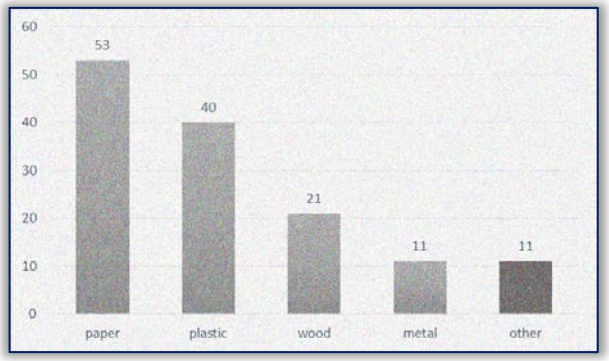

Figure 6/a. Preferred packaging materials [Source: own editing]

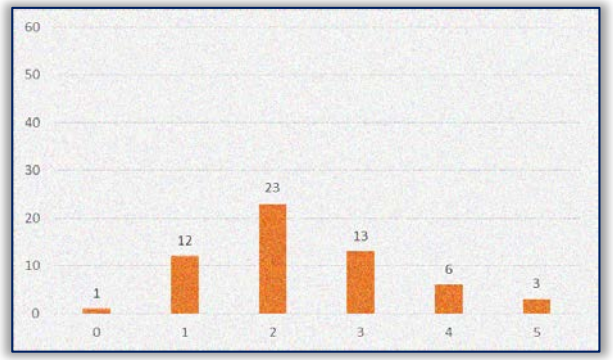

Figure 6/b. Number of responses for packaging [Source: own editing]

Other categories include glass, stainless steel, or recycled materials. It is also important to note that three-quarters of companies produce more packaging.

— Convenient unit clamping, facilitating the use of the product

The next major category has been the packaging technology options to facilitate practical unit inclusion and product use (handling). In connection with this, six requests were made. The first question was based on which the packets are grouped (Figures 7/a and b).

The number of units stands out in terms of responses, most notably the unit of measure most often used by the companies surveyed in the county. It was also possible to give the option of more than one answer, but it can be seen that more than half of the answers mainly consider one aspect when enrolling in the unit. Breaking down the topic of consolidation, how packaged products come from each company was sought below (Figures 8 / a and b).

The most popular packaging destination is unit load training, followed by collective packaging. Due to the number of possible answers, Figure 8 / b shows that more than 2/3 of the companies use products for more than one purpose. The following question was related to the previous one, namely, what kind of packaging methods are used within the collective packaging, as this category can be very diverse due to the task of the packaging type (Figures 9/a and b).

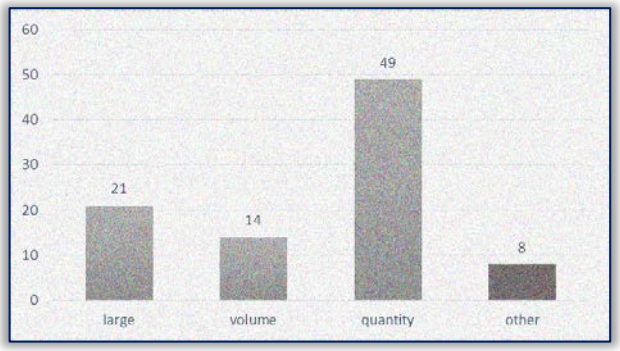

Figure 7/a. Type of aspect of unit inclusion
[Source: own editing]

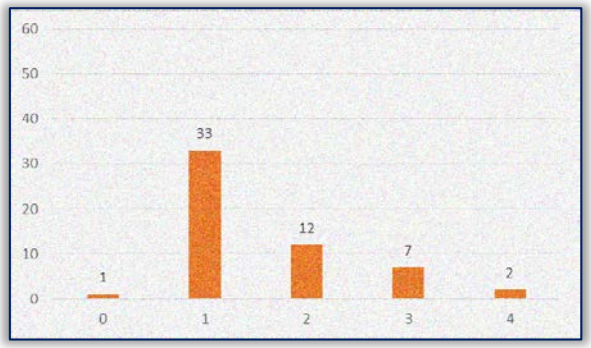

Figure 7/b. Number of responses in terms of unit inclusion
[Source: own editing]

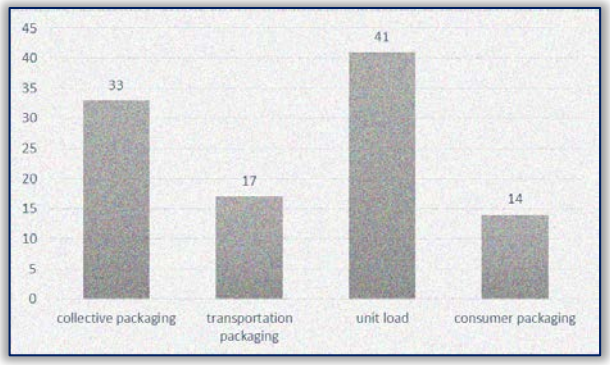

Figure 8/a. Type of final packaging unit
[Source: own editing] [1]

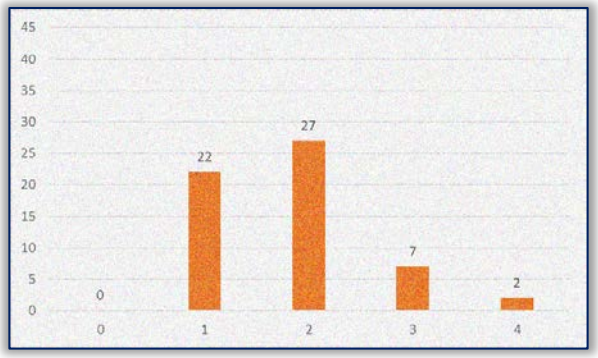

Figure 8/b. Number of responses according to the intended use of the packaging
[Source: own editing]

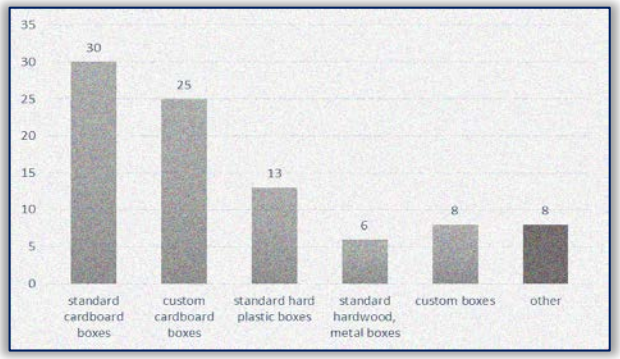

Figure 9/a. Types of collective packaging
[Source: own editing]

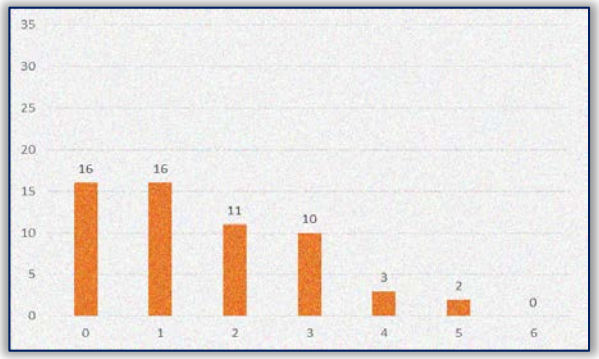

Figure 9/a. Number of responses for types of collective packaging
[Source: own editing]

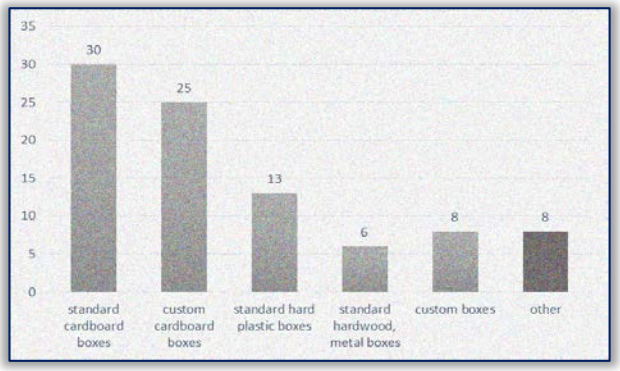

Figure 9/a. Types of collective packaging
[Source: own editing]

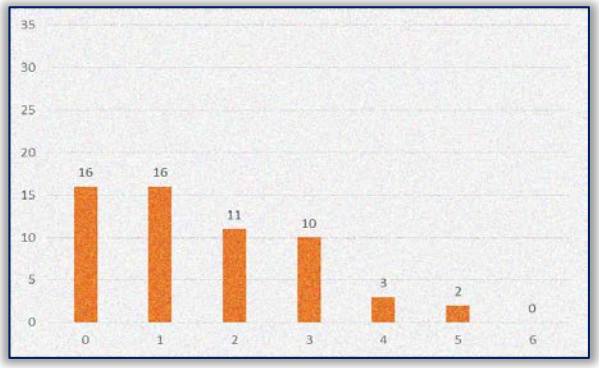

Figure 9/a. Number of responses for types of collective packaging
[Source: own editing]

[1] Collector: the packaging of a packaged or unpackaged product into a larger unit; Transport: usually complex packaging to facilitate catching, moving, transporting and storing the unit; Unit load: with the help of aids, e.g. EUR pallets, packaged or unpackaged products; Consumer packaging: the packaging that accompanies the product to the consumer (as interpreted by the authors).

In connection with the question, the main stakeholders are the extent to which the respondents use standard units and the typical use of collective packaging according to individual devices and sizes. In terms of devices, the diagrams show that the number of applications of standard and custom devices is quite divided. In terms of the number of responses, quite a few companies did not answer because they do not use collective packaging. In connection with the delivery process, we asked questions mainly to assess the properties and aspects related to the means of transport (Figures 10/a and b).

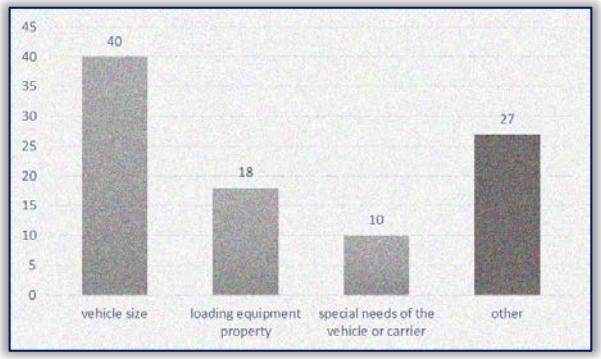

Figure 10/a. Aspects related to the delivery process
[Source: own editing]

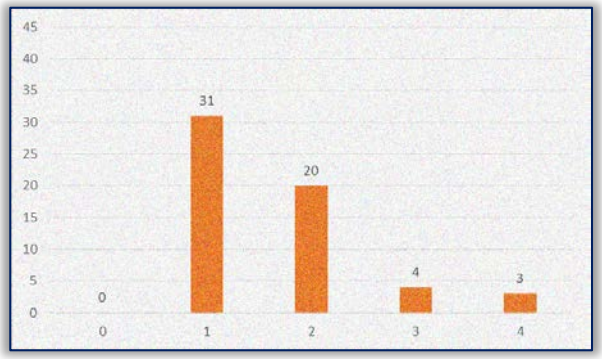

Figure 10/b. Number of responses related to shipping
[Source: own editing]

In connection with the delivery process, the size of the means of transport is the most decisive, and companies need to adapt to it the most, but an 'Other' category was also given here, which was also very popular. These include, for example, the size of the pallets and containers, customer and marketing needs, hygiene considerations, temperature, or size restrictions that can be sent by air. Nearly half of the companies mentioned several aspects here as well. Several aggravating factors can occur within companies when placing products in packaging. The following question is asked (Figure 11/a and b).

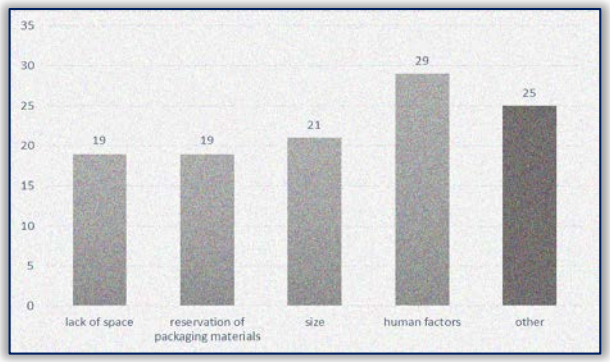

Figure 11/a. Aggravating factors for in-house packaging
[Source: own editing]

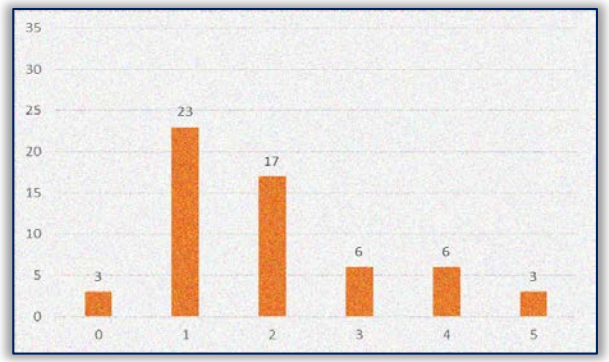

Figure 11/b: Number of responses regarding aggravating factors
[Source: own editing]

Most of them indicated the kind of place or places, in the sense that either there is not enough space to do the packaging, or the packaging materials took up too much space. In the Other category, cases such as many parties, different packaging sizes, manual work, and little time to complete packaging were indicated. Some referred to weight problems, and machine shops were standard.

— Sales promotion

About the fifth sub-area, the promotion of sales was marked, in connection with which the tools and operations that help them in the final phase of packaging were assessed from the side of the companies (Figures 12/a and b).

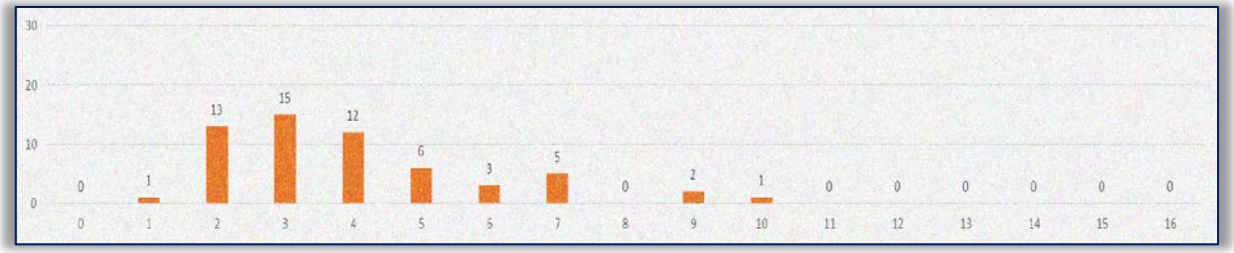

Figure 12/a. Number of responses for final operations [Source: own editing]

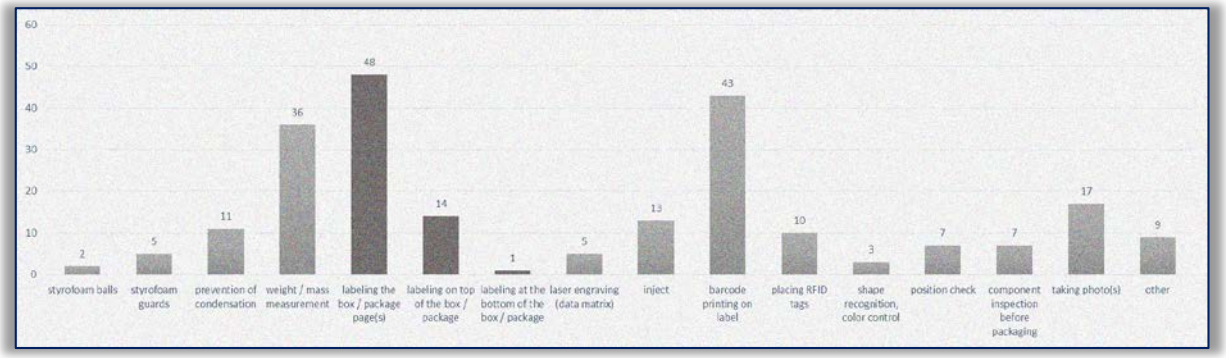

Figure 12/b. Evolution of final packaging operations among respondents [Source: own editing]

Before selling, the most popular operation is mainly labelling the package's side, bottom, and top but closely following the barcode printing on the label. It can be seen in Figure 12/a that the vast majority of respondents consider at least two additional operations to be necessary, but five, six or even seven follow-up operations are not uncommon.

5. χ^2 test to explore correlations

After analyzing the answers to the questionnaire, the answer to whether there is a correlation between the packaging material and the packaging material chosen for protection against external influences was sought using the χ^2 test. During the literature search and the compilation of the questionnaire, these two factors came to the fore in connection with the packaging technical tasks and perspectives of a company. Based on these, the hypothesis was set up as follows:

- H_0: The choice of packaging material and the protection of the packaging material against external influences are not statistically independent. There is dependence.
- H_a: The choice of packaging material and the protection of the packaging material against external influences are statistically independent.

To perform the test, the first step was to quantify the text response to the questionnaire, for which binary coding was chosen. If the answer was checked, it was given a value of 1, where it was not 0. There was a 2x2 lookup table between the sub-items of each question. The expected value was constructed from the cross-tabs and the χ^2 test using the following formula.

$$\chi^2 = \sum_{i=1}^{r} \sum_{j=1}^{c} \frac{(O_{ij} - E_{ij})^2}{E_{ij}}$$

where:

- O_{ij}= the actual frequency of the i-th row and the j-th column,
- E_{ij} = the expected frequency of the i-th row and the j-th column,
- r = number of rows,
- c = number of columns.

The elements compared and the result of the χ^2 test are shown in Table 1.

Table 1: Function values for the χ^2 test [Source: own editing]

		Does your packaging protect against the external influences of individual packaging products?			
		B1- mechanical	B2- climatic	B3- biology	B4-other
Which packaging materials are used?	A1-paper	0.3429	0.8535	0.2578	0.0232
	A2-plastic	0.5769	0.1371	0.6713	0.0563
	A3-wood	0.0780	0.0124	0.4784	0.2643
	A4-metal	0.2578	0.4784	0.3534	0.1540
	A5-other	0.9508	0.1598	0.3534	0.1540

It can be seen from the table that if $\alpha = 0.05$, the significance level is 95%, then after performing the test, we can find a correlation between the analyzed aspects in two cases. In the case of Hungarian industrial companies, there is a clash between the use of paper and other goods in need of protection, including electrostatic protection or protection against dust and external contaminants. A further relationship has been discovered between the use of wood and climatic stress, which are not statistically independent of each other. In all other cases, the null hypothesis was invalid. The choice of packaging material and the protection against external packaging influences were statistically independent. The following is a summary of the results.

6. CONCLUSION

The questionnaire survey revealed that the survey of the current situation of the companies shows a very mixed picture even in the case of a small sample (n = 58). One of the most common parameters is that the products do not require special rules. Protection against mechanical effects is paramount. The number of units is most typical when booking a unit. The need for space was most often mentioned as an aggravating factor somehow. When delivered, the endowment of the vehicles was most often mentioned as a determining parameter. Paper and plastic have been used most often for packaging, not surprisingly. According to the purpose of the packaging, the products come out of the companies in unit loads or collective packaging. For packaging devices, there are a wide variety of responses regarding the material, size, weight, shifts, and quantities of the packaging device.

After performing the Chi-square test, the analysis of the correlation between the protection function of the packaging material and the packaging against external influences revealed that at a significance level of 0.05, there is a statistical correlation in two cases, paper-other protection and wood-climatic protection. For each additional pair, the null hypothesis is to be discarded. There is no detectable statistical dependence.

The questionnaire survey's primary objective was to provide a general picture of the current state and needs of packaging technology in Hungarian companies. The analysis revealed that companies are aware of the need to build and develop modular end-of-line packaging technology to serve their customers' needs quickly and increase efficiency within the company. However, they have difficulties defining their exact needs. The parameters related to packaging technology are very variable in the life of industrial companies. Therefore, the correlation analysis has not provided a clear answer as to whether there is a statistical dependence between the type of packaging and the external effects that each type of packaging protects against.

As a significant limitation of the research, it is necessary to mention that a tiny sample was analyzed, which could not give a completely comprehensive picture. An additional limitation was that the questionnaire questions were very focused only on the issues of packaging technology. They did not specifically address the issues of waste management, sustainability or cost-effectiveness, which were for the design of future logistics systems.

The questionnaire survey also shows how complex and complicated it is for a company to define its tasks and properties related to packaging technology, but it is also an important area for both Industry 4.0 and for seeing the sustainable logistics systems of the future. Our research concluded that although there is a need to analyze packaging technology, Hungary has little research. Further research is needed to explore the more detailed picture.

Acknowledgement

This research is supported by 2020-1.1.2-PIACI-KFI-2020-00062 "Development of an industrial 4.0 modular industrial packaging machine with integrated data analysis and optimization based on artificial intelligence, error analysis". The Hungarian Government supports the Project and is co-financed by the European Social Fund.

Reference

[1] Bababode Adesegun Kehinde, Ishrat Majid, Shafat Hussain, Vikas Nanda, 13 - Innovations and future trends in product development and packaging technologies, Editor(s): Bhanu Prakash, Functional and Preservative Properties of Phytochemicals, Academic Press, 2020, 377-409, https://doi.org/10.1016/B978-0-12-818593-3.00013-0.

[2] Voice Moyo, Packaging waste and their management technologies, In The Textile Institute Book Series, Waste Management in the Fashion and Textile Industries, Woodhead Publishing, 2021, 145-155, https://doi.org/10.1016/B978-0-12-818758-6.00007-7.

[3] Dong Sun Lee, Hong Jiang Wang, Packaging of Milk and Dairy Products: Packaging Materials, Technologies and Their Applications, Reference Module in Food Science, Elsevier, 2021, https://doi.org/10.1016/B978-0-12-818766-1.00259-2.

[4] Dörnyei, Krisztina. (2019). Csomagolásmenedzsment. Kossuth Kiadó Zrt.

[5] Eva Almenar, Innovations in packaging technologies for produce, Chapter 11, Controlled and Modified Atmospheres for Fresh and Fresh-Cut Produce, Academic Press, 2020, 211-264, https://doi.org/10.1016/B978-0-12-804599-2.00012-0.

[6] Gordon L. Robertson, History of Food Packaging, Reference Module in Food Science, Elsevier, 2019, https://doi.org/10.1016/B978-0-08-100596-5.22535-3.

[7] Hongxia Sun, Jiali Li, Behavioural Choice of Governments, Enterprises and Consumers on Recyclable Green Logistics Packaging, Sustainable Production and Consumption, 2021, https://doi.org/10.1016/j.spc.2021.06.011.

[8] Jesús García-Arca, Alicia Trinidad González-Portela Garrido, J. Carlos Prado-Prado, Packaging Logistics, Editor(s): Roger Vickerman, International Encyclopedia of Transportation, Elsevier, 2021, 119-129, https://doi.org/10.1016/B978-0-08-102671-7.10230-1.

[9] Ishrat Majid, Gulzar Ahmad Nayak, Shuaib Mohammad Dar, Vikas Nanda, Novel food packaging technologies: Innovations and future perspective, Journal of the Saudi Society of Agricultural Sciences, 17, 4, 2018, 454-462, https://doi.org/10.1016/j.jssas.2016.11.003.

[10] Masoud Ghaani, Carlo A. Cozzolino, Giulia Castelli, Stefano Farris, An overview of the intelligent packaging technologies in the food sector, Trends in Food Science & Technology, 51, 2016, 1-11, https://doi.org/10.1016/j.tifs.2016.02.008.

[11] Mike Vanderroost, Peter Ragaert, Jan Verwaeren, Bruno De Meulenaer, Bernard De Baets, Frank Devlieghere, The digitization of a food package's life cycle: Existing and emerging computer systems in the logistics and post-logistics phase, Computers in Industry, 87, 2017, 15-30, https://doi.org/10.1016/j.compind.2017.01.004.
[12] Monirehalsadat Mahmoudi, Irandokht Parviziomran, Reusable packaging in supply chains: A review of environmental and economic impacts, logistics system designs, and operations management, International Journal of Production Economics, 228, 2020, 107730, https://doi.org/10.1016/j.ijpe.2020.107730.
[13] Nathalie Silva, Henrik Pålsson, Industrial packaging and its impact on sustainability and circular economy: A systematic literature review, Journal of Cleaner Production, 333, 2022, 130165, https://doi.org/10.1016/j.jclepro.2021.130165.
[14] Simon P. Washington, Matthew G. Karlaftis, Fred Mannering, Statistical and Econometric Methods for Transportation Data Analysis (Chapman & Hall/CRC Interdisciplinary Statistics), 2nd Edition, 2010
[15] S.J. Eilert, New packaging technologies for the 21st century, Meat Science, 71, 1, 2005, 122-127, https://doi.org/10.1016/j.meatsci.2005.04.003.
[16] Yong Wang, Shouguo Peng, Xuesong Zhou, Monirehalsadat Mahmoudi, Lu Zhen, Green logistics location-routing problem with eco-packages, Transportation Research Part E: Logistics and Transportation Review, 143, 2020, 102118, https://doi.org/10.1016/j.tre.2020.102118.

ISSN 1584 – 2665 (printed version); ISSN 2601 – 2332 (online); ISSN-L 1584 – 2665