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ANALYSIS OF THE TYPES AND EFFECTS OF POSSIBLE ERRORS IN THE IMPLEMENTATION OF ECOLOGICAL REUSABLE PACKAGING INTO E-COMMERCE USING FMEA

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ABSTRACT: One of the most important features of the e-commerce logistics process is its reliability. It is obtained by properly planning the process and then ensuring its course is in accordance with the developed plan and all procedures. As the data show, most problems appear at the stage of designing and preparing products and processes for implementation. Detecting potential causes of non-compliance can help prevent unwanted events from occurring. The aim of the article is to identify and assess the risk for the process and product in terms of the possibility of using reusable packaging in e-commerce logistics services provided by ARVATO Polska Sp. z o. o. with its registered office in Warsaw, taking into account preventive and corrective actions in relation to the risk. Through the use of research methodology in the form of risk mapping, 13 potential risk factors were identified, and recommendations were formulated to avoid and mitigate the effects of disruptions. Among the identified risk factors, the quality of the packaging itself, including the appropriate packaging material and the level of packaging flexibility, turned out to be the most important. The conclusions of the study may have practical applications to improve the functioning of cost-effective and environmentally friendly e-commerce logistics. The importance of these analyses increases in the assessment of innovative solutions that can be considered as the use of ecological returnable packaging in e-commerce logistics. Their goal is to identify and eliminate possible packaging failures on the market.

KEYWORDS: e-commerce, ecological packaging, supply chain, sustainable development

Introduction

From the very beginning of life on Earth, man has influenced his environment. Drawing from the resources needed for life, he often had a negative impact on them, thus reducing the availability of goods on which he depended. Also, today, the rapid development of industry, as well as the increase in the population, entails degradation and pollution of the environment (Majerník et al., 2021). The constantly growing amount of waste generated has forced the public to become interested in pro-ecological activities, including in the field of resource management, environmental protection and waste management. The current trend is to minimise the risks closely related to waste (Karali & Shah, 2022; Szołtysek & Twaróg, 2017).

Concern for the quality of the environment has become an important element of marketing for many organisations, in particular in terms of shaping their image in public opinion. In the era of increasing competition between enterprises, traditional management tools, such as lowering production and logistics costs, improving the internal organisation of enterprises or even improving the quality of manufactured products, are no longer effective in the fight for market success (Sharma et al., 2020). On the other hand, the intensity of pollution caused by manufacturing and commercial activities is now reaching its maximum, thanks to the growing group of companies producing more and more products with ever shorter lifespans. At the same time, consumers increasing awareness of the deteriorating environment puts additional pressure on companies to include environmental considerations in their production and marketing plans (Block, 2009; Zhu & Shah, 2018).

Packaging performs important functions in the protection and advertising of a given product, and its importance has an increasing impact on attracting the customer's attention (Singh et al., 2019). Together with economic development and technological progress, they play an increasingly important role. Recycling and caring for the environment are very important issues these days. It is important that as little waste as possible ends up in the environment and that as much of it can be recycled and reused with proper treatment (Manavalan & Jayakrishna, 2019). Hence, extending the life cycle of packaging as a result of introducing reusable packaging and designing packaging, in accordance with the assumptions of the circular economy are increasingly treated as a priority in the development strategies of enterprises. Packaging is most often made of plastic, glass, metal and, increasingly, of paper, which is the easiest to recycle. It is also important that the packaging contains an exact description of what material it was made of so that the consumer can throw it into the appropriate waste container. More and more often, you can find packaging of new products that have been obtained from

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recycling, thanks to which less waste is released into the environment, which may pose a threat to both the environment and the human being. It is important to pay attention to the material from which the packaging is made and that the customer himself is aware that his product is sold at the right price and at the same time is environmentally friendly (Górniak & Bukowska-Piestrzyńska, 2020). Improperly disposed of packaging may pose a serious threat to the natural environment, i.e., emission of harmful substances into the atmosphere, water and soil pollution, chemical composition (especially heavy metals, harmful substances), overloading of landfills or consumption of resources (Granato et al., 2022; Korzeniowski et al., 2012).

The role of packaging is a very important aspect in the area of logistics and distribution because it is thanks to them that the product reaches the customer intact. In addition to the quality of workmanship, it is also important to improve the quality of environmental protection (Silva & Palsson, 2022). The sustainable development strategy allows for the introduction of measures to minimise the excessive depletion of natural resources in order to maintain the durability and self-sufficient development, and at the same time, ensures that the quality of life of the society is maintained at the same level. Thanks to such activities, companies care for the environment, the demand for natural resources is reduced, the amount of waste is reduced, and less pollution is emitted into the atmosphere. The use of reusable packaging or packaging that can be easily processed and recycled is cost-effective and competitive. Labelling packaging with symbols that show that they are environmentally friendly allows you to encourage and convince the customer to make more frequent purchases because he is more aware that thanks to such activities, he cares about the environment (Cooper & Gutowski, 2017).

According to the adopted thesis, the introduction of ecological reusable packaging for e-commerce is a strategic decision of the organisation from the point of view of the efficiency of supply chains. The aim of the article is to analyse the types and effects of possible errors in the process of implementing ecological reusable packaging in e-commerce logistics services using the FMEA method. Research questions were formulated for this specific purpose:

How to shape the decision-making process on the implementation of ecological reusable packaging in e-commerce services to reduce the frequency of risk factors as much as possible?

How to manage risk in e-commerce supply chains, taking into account not only the profitability of reusable packaging and the operational efficiency of chains, but also the increasingly difficult access to resources, climate change and social needs?

The issue of returnable unit packaging is at the initial stage of research projects. The systemic approach used by the authors in the study of reusable ecological packaging in the sustainable development of circular e-commerce

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contributes to reducing the research gap in this thematic area and provides practical implications for organizations in terms of risk management. Decisions related to the implementation of a new product – ecological reusable packaging – are burdened with numerous risk factors, both for the organization and stakeholders. Hence, the assessment, control and monitoring of risk with the use of decision-making tools is a manifestation of the organization's maturity and responsibility towards stakeholders, including the environment.

The research results presented in the article are part of the project implemented in 2021 under the research and development contract commissioned by Arvato Polska Sp. z o.o. with its registered office in Warsaw. The authors of the article present selected results of analyzes that were carried out for one of the research tasks of the project, i.e. the diagnosis of risk factors in the use of reusable ecological packaging in e-commerce logistics services[1].

Literature review

The efficient functioning of production and logistics processes results from the implementation of appropriate management concepts and taking actions to maintain the required quality standards throughout the supply chain (Lima-Junior & Carpinetti, 2020; Khan & Naeem, 2018). Quality and the way it is shaped is the basis for an effective organisational strategy that enables meeting customer expectations in terms of the quality of the products or services offered. The purpose of implementing specific concepts or management systems is to strive for continuous improvement of processes that allow to maintain an appropriate market position and adapt to changing environmental conditions. Quality, which is one of the elements subject to continuous improvement, plays a special role in this (Khan et al., 2020; Xie et al., 2019).

The literature on the subject of project management clearly identifies the most important criteria according to which the processes and effects of production implementation are assessed, such as time, costs, scope, quality and human resources (Wei et al., 2021; Abreu et al., 2022). Defined deadlines, compliance with the allocated budget, the project's purpose, and contractors' competencies and commitment to implementation are elements that require proper planning, scheduling and work patterns. Fulfilment of specific requirements determines the fulfilment of complex conditions of implementation: technical, functional and visual, which are related to the final effect of

1 Due to the applicable "data confidentiality" clause, the article presents selected results of the analyses.

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the project and prove its quality. These elements form the main group of success factors, at the same time being the basis for achieving the goal and customer satisfaction (Pham, 2020).

The FMEA method was developed in the USA during the preparations for the Apollo program in the first half of the 1960s. Its purpose was to support the analysis of space systems designs (rockets, flight control systems) and the production processes of these components in order to identify potential system failures as a result of adopting incorrect assumptions or design solutions. The successful flight to the Moon was an effective validation of the method and a recommendation for its use in other areas (Tsai et al., 2017). The FMEA method is based on the analytical determination of cause-and-effect relationships for the formation of potential product defects and taking into account the criticality factor (risk) in the analysis. Its goal is to consistently and systematically identify potential product/process defects and then eliminate them or minimise the risk associated with them (Moreira et al., 2020).

FMEA is a method of identifying and preventing problems related to the analysed process before its implementation (Carbone & Tippett, 2004). Focuses on preventing defects in the process or product, increasing process safety, project financial security, occupational safety and environmental protection (Chauhan et al., 2018). The FMEA method is used to analyse the types and effects of possible errors that may occur in the design and development phase. Thanks to the use of this method, it is possible to subject the product or process to further analyses and then, based on the obtained results, to introduce improvement actions (i.e. all kinds of corrections, and new solutions) that will contribute to the effective elimination of sources of defects. The most important benefits related to the implementation of the FMEA analysis include (Casado et al., 2023; Velasquez & Lara, 2017):

- continuous improvement of products and production processes,
- continuous elimination of potential sources of defects,
- reduction of production costs,
- reducing the number and costs of complaints,
- increase in product quality,
- greater reliability, and thus – greater customer confidence.

Thanks to the FMEA method, it is possible to continuously improve the product/process by subjecting it to subsequent analyses and, based on the results obtained, introducing new corrections and solutions that effectively eliminate sources of defects and provide new ideas for improving product properties. It can be used for very complex processes, both in mass and unit production (Almannai et al., 2008; Kumru & Kumru, 2013).

With FMEA, the possibilities are improbable, but without FMEA, the possibility is only probable (Oakland, 2014). One of the key factors determining

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the effectiveness of production and service activities are logistics processes, consisting of the physical flow of goods through subsequent phases of economic activity. The logistics process is often a service process, auxiliary to the basic process, satisfying a specific need – the production of a specific good. The quality and timeliness of the implementation of such supporting logistic processes determine the quality, timeliness and costs of the basic manufacturing process carried out in the system of business activity of the enterprise (Jüttner, 2005; Ennouri, 2013; Bai et al., 2018). Logistics process management is a process of comprehensive planning, organisation and control of logistics processes and activities carried out to ensure efficient and effective flow of materials, semi-finished products and final products in enterprises as well as logistics and supply chains (Colicchia & Strozzi, 2012).

The analysis of logistics processes is not a new research issue, but it is gaining special importance in the modern market, primarily because it is a factor in the fight against competition (Castillo, 2023; Hu et al., 2020). Knowledge of the logistics system and the processes taking place in it is of great importance for the efficient and effective logistics operation of any organisation. The functioning of companies on global markets requires effective logistics, which is why it is necessary to constantly search for tools to improve its processes (Liu et al., 2023; Birkel & Hartmann, 2020).

Materials and methods

When identifying and assessing the risk, an FMEA analysis was performed, illustrated with a risk matrix. The conducted FMEA analysis covers such areas of reusable packaging design and marketing as: technological, time, location, economic, economic, social and environmental areas. The risk analysis took into account the conditions related to the development and implementation of ecological reusable packaging for the fashion industry, affecting the transformation of supply chains in e-commerce. The review of the literature shows that this is a new area of analysis, which is in the initial phase of research. In order to obtain theoretical saturation, the study used conclusions from observations during two study visits to distribution centres carried out in 2021 and the results of structured interviews. Interviews with experts were conducted as part of 3-panel meetings in February – June 2021. The professional knowledge and practical experience of the speakers were used to assess the substantive correctness of the measurement (Zhu et al., 2021). The group of experts included representatives of the Arvato management board, members of the management staff and managers responsible for the implementation of e-commerce orders at various stages of the supply chain.

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The research procedure consisted of four stages.

The first stage focused on assessing the severity of the problem. Individual activities were analysed in the context of developing ecological reusable packaging for use in e-commerce logistics in terms of the process and product itself. Design FMEA (DFMEA) and process FMEA (PFMEA) are the most common types of FMEA analysis that have been incorporated into the ISO 9001 quality system (Wang, 2018). In order to assess the significance of the problem, the potential type of defect along with its effect was determined. There are different scoring methods in the risk assessment and management literature (Zhu & Shah, 2018). Based on the scale proposed by Liu et al. (2013), the probability of a defect (S) was rated on a scale of 1 to 10 (Liu et al., 2018). An improbable situation was assigned a value of 1, and a very probable situation a value of 10.

The second stage is concerned with determining the cause of the defect along with determining its value. Also, in this case, the cause of the failure was determined on a scale of 1 to 10. The value of 1 was assigned to a low probability situation (no possibility of failure) and 10 to a situation with a very high probability of the occurrence of a defect (O).

In the third stage, preventive actions / ongoing control of e-commerce logistics services were defined, and the detection parameters (D) were estimated, which were assigned values on a scale from 1 (very high importance – reliable detection of the defect) to 10 (very low importance – detecting the defect is difficult or impossible).

The fourth stage of the FMEA analysis consisted in determining the RPN parameter. Assigning the above parameters to the FMEA sheet made it possible to determine the RPN risk priority number, which was calculated according to the following formula:

$$\text{RPN} = \text{Severity (S)} \times \text{Occurrence (O)} \times \text{Detection (D)}. \quad (1)$$

RPN allows you to determine which threats carry the greatest risk and indicates the hierarchy in which order preventive actions should be initiated. The research was aimed at demonstrating the relationship between determinants, sources of risk, and the implementation of ecological reusable packaging for use in e-commerce logistics services. During the analysis, the value of RPN=100 was established, below which the impact of potential risk factors on the packaging development process is insignificant.

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Results of the research

On the basis of previous analyses and selection of conditions as well as developed Ishikawa diagrams (Motowidlak & Tokarski, 2022), an FMEA analysis of ecological reusable packaging for use in e-commerce logistics services was carried out in terms of process (understood as e-commerce logistics services using ecological reusable packaging) and product (understood as ecological reusable packaging. The results are presented in Table 1.

Table 1. FMEA analysis sheet for the use of reusable packaging in e-commerce logistics

No.	Potential type of fault	Potential effect of the defect	Severity (S)	Potential cause of failure	Occurrence (O)	Preventive actions/ Ongoing control of e-commerce l ogistics services	Detection (D)	RPN
1	Perishable packaging material	Damage to the goods	8	Selection of material that does not meet transport requirements	8	Adjusting the transport space of the vehicle by arranging shipments in racks specially designed for this purpose	6	384
		The packaging may tear if there are sharp objects inside	8	The packaging material is unstable, no filler	5	Evaluation of the quality of returnable packaging – individual and collective (system changes)	6	240
2	Limited package rigidity	Materials in the packaging move even with the use of filler, which affects the unsightly appearance of the order	6	Choosing the right packaging material	6	Pilot study using reusable packaging Identification of real disturbances, assessment of process efficiency	8	288
3	Non-permanent closure	Due to the dimensions of the package, the zipper may jam in the corners when closing	7	Packages are not scalable	4	Taking special care	6	168
		The plastic zipper in the envelope may not be durable after prolonged use	7	Unsuitable material	6	Choosing the right material	5	210
4	Delicate handle	Detaching the handle from the packaging	7	Unsuitable/ perishable material	6	Choosing the right material or making the handle functional	6	294

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A relatively lower probability of occurrence, but also associated with the occurrence of significant consequences, was indicated in the case of packaging susceptibility to dirt, non-permanent closure, impractical sealing and non-durable handle. The average level of probability of occurrence and risk effects for activities related to the problem of scanning the label and its insertion or removal from the place intended for this, the lack of an appropriate packing station, as well as the lack of liability procedures for packaging damage at a given stage were determined.

For the Premium packaging process, a low probability of occurrence and effects was indicated. Low probability, but with an increasing tendency in terms of consequences, was noted in terms of their impact on the level of customer loyalty towards the company. The risk matrix is presented in Table 2.

Table 2. Risk matrix of using reusable packaging in e-commerce logistics

After-effects				
	High		• Perishable packaging material • Limited package rigidity • Incorrect packaging size for the product • Susceptibility of the packaging to dirt • Non-permanent closure	Perishable packaging material Limited package rigidity
	Medium	Decreased customer loyalty to the company	• Label scanning problem • The courier label does not fit in the designated area • Lack of a suitable packing station • No entity responsible for packaging damage at a given stage	
	Low	Complicating the premium packaging process		
		Low	Medium	High
		Probability		

* Scale: 0-1 none, 2-3 low, 4-5 medium, 6-9 high

The conducted diagnosis of the area of potential threats in the project allows us to draw the following conclusions and formulate the following recommendations. 13 potential risk factors were indicated, i.e. unstable packaging material, limited packaging rigidity, unstable closure, unstable handle, impractical closure, incorrect packaging size for the product, susceptibility to dirt, the problem with scanning the label, courier label does not fit in the designated place, the complexity of the Premium packaging process, the lack of an appropriate packaging station, reduced customer loyalty

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towards the company, as well as the lack of an entity responsible for packaging damage at a given stage. The most important of these turned out to be the quality of the packaging itself, including the appropriate packaging material and the level of packaging flexibility. In order to prevent damage to the goods during transport, it is recommended to select a material that meets the transport requirements, as well as to adjust the transport space of courier vehicles by placing shipments on specially designed racks.

In the case of products moving inside the packaging, even despite the use of filler, which affects the unsightly appearance of the order, it is recommended to choose the appropriate packaging material (paper pulp, foam plastic, corrugated or proposed cardboard), e.g., other lightness, physical and chemical resistance related to with disinfection, unlike corrugated cardboard packaging, it is more durable and less susceptible to damage during transport, fully recyclable, reusable. Printing the QR code on the packaging (using a dynamic link) will allow you to opt out of shipping labels and change the destination URL for subsequent customers using reusable packaging.

Suggested examples of risk mitigation solutions in the e-commerce supply chain using sustainable, reusable packaging could be avoidance, control, collaboration and flexibility. They should be included in strategic and tactical activities that can increase their effectiveness in mitigating potential threats to the supply chain and e-commerce in accordance with the assumptions of sustainable development, as confirmed by research (Yousefi & Tosarkani, 2022).

Conclusions

Taking into account the adopted main objective and research questions, the results of the conducted analyses indicate several important findings confirming the accuracy of the thesis.

Based on the research results presented in the article, it can be concluded that the improvement of the quality of e-commerce logistics services with the use of ecological returnable packaging is a reflection of the efforts of Arvato Polska, based in Warsaw, to implement environmentally friendly and economically effective solutions. It is recommended to pay due attention to the area of contact with individual customers and build their loyalty towards the company. Lack of or too slow a pace of acceptance of new packaging by potential individual customers may reduce their loyalty to the brand. The essence of this issue is presented in their research, e.g. Zhu et al. (2021). The phenomenon of excessive consumption is characteristic of modern society, it concerns each of us, and the consumer lifestyle is becoming more and more common. Limited resources force us to look for the optimal solution to

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achieve maximum benefits from the consumption of both food and clothing. In the theory of the consumer, it is assumed that he is a rational being who, when making decisions, strives to achieve the greatest possible benefits that can be achieved from the consumption of goods under given conditions (Abdelradi, 2018). A rational consumer bases the decision-making process on the principle of optimisation, when buying a specific product or service, he has individual preferences. With the growing popularity of e-commerce, the potential consumer began to look for new solutions that would allow him to save not only money but also time with due care for the environment (Mason et al., 2022). Building a relationship with an individual customer is particularly important when introducing new packaging to the market and withdrawing the packaging to which he has become accustomed from the offer. An important solution is the introduction of a loyalty package for regular and new stakeholders, e.g. in the form of requests for orders and returns, collecting loyalty points that allow you to reduce the amount of the deposit and take advantage of promotions. The implementation of Smart Packaging tools will stimulate consumer loyalty, increase their purchasing decisions and increase the transparency of product production.

The observations during the study visits and the conclusions of the study show that the greatest impact on the development of ecological reusable packaging for use in e-commerce logistics has technological aspects, primarily related to the strength of the packaging material, its size, stiffness, durability and purity. Particular attention should be paid to the durability of the closure of the package, as well as the practicality of using the seal and the handle. Other aspects affecting the risk management of the analysed process are the problems associated with scanning the label, the lack of an appropriate packing station, as well as the lack of procedures in the area of responsibility for packaging damage at a given stage of transport. Less important, but requiring verification and control, are the risk factors related to the complexity of the Premium package packaging process and the reduction of customer loyalty towards the company.

The originality of the conducted research was achieved through their measurable character. Potential risk factors identified with the FMEA method and formulated recommendations for avoiding and mitigating the effects of disruptions can be useful in improving the functioning of cost-effective and environmentally friendly e-commerce logistics. One of the key challenges in the field of future research directions may be the study of interrelationships between individual risk factors using the DEMATEL method (Tsai et al., 2017). The article does not formulate unambiguous strategies and tactics of solutions aimed at reducing the identified threats. A prerequisite for successfully completing such a task is the availability of a comprehensive and accu-

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rate dataset that includes more fashion case studies. The results of this analysis indicate that this may pose another challenge for future research.

The contribution of the authors

Establishing the concept, D.T. and U.M.; establishing research methods, D.T. and U.M.; creating text, D.T. and U.M.; analytical description of the phenomenon, D.T.; implementation of the research idea, D.T. and U.M.; critical assessment, D.T.; data collection, D.T. and U.M.; data analysis and interpretation, D.T. and U.M.; development of research results, D.T. and U.M.; review of the literature, D.T. and U.M.

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