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Article

Innovative solutions in the warehousing processes of manufacturing companies towards sustainability

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Abstract: Development of technologies and innovations encouraged companies to look for and implement innovative solutions in their practice seeking not only to increase the efficiency of activity but also towards sustainability. In this context, the aim of the research is to reveal innovative solutions for the improvement of the warehousing processes towards sustainability in the case of manufacturing companies. The methodological setup consists of two steps. First, a comprehensive literature analysis was conducted seeking to reveal and present a theoretical model based on the conceptual framework on this topic. Then, a semi-structured interview was conducted with 8 managers holding managerial positions in four Lithuanian manufacturing companies. The manufacturing companies were chosen for the research due to their durable experience in the market, which use advanced warehouse management methods in their operations. Main findings showed, that innovative solutions such as Big Data Datasets, smart networks, Drones, Robots, Internet of Things and etc., are important for the efficient warehousing processes. Furthermore, it is also necessary to emphasize the benefits of implementing of innovative solutions in warehousing processes not only in economic terms, but also for solving of social and environmental issues towards sustainability. The novelty of this study lies in its dual objective of filling a theoretical gap and of drawing the attention of companies and policy makers to the importance of innovative solutions implementation in the warehousing process towards sustainability.

Keywords: innovative solutions; sustainability; warehousing processes; manufacturing companies

1. Introduction

Increasing competition in the market encourages companies to look ways for better consumers' service and to optimize the processes taking place in the company, while at the same time achieving sustainability. Sustainability is understood as the ability to meet the needs of the present without compromising the ability of future generations to meet their needs. Sustainability involves balancing environmental, social and economic factors, ensuring long-term viability and resilience. The concept of sustainability is closely linked to the United Nations' Sustainable Development Goals (SDGs), which are a global call to action to end poverty, protect the planet, and ensure peace and prosperity for all (Kumar et al., 2024). When we discuss about sustainability, we must emphasize the importance of sustainable innovations, because these concepts are closely related (Ali et al., 2023; Pastoors et al., 2017). Sustainable innovation aims to eliminate unintended environmental and social consequences. This means that companies can provide services and products that benefit themselves and society in the long term. Sustainability-oriented innovations linked to the changes of

companies' values and philosophies and their services, processes or products. According to Jum'a et al. (2022), sustainable innovations have the highest influence on economic sustainability. Other scholars argue that it is possible to obtain not only economic, but also to realize social and environmental returns (Adams et al., 2016). Sustainability-oriented innovation also positively influences the activities of the entire company (Du et al., 2022). The main goal of sustainable innovation is to create new products and technologies that have a positive impact on the company's "triple-bottom-line". Thus, the company's processes must be ecological and economical, while at the same time beneficial to the company and socially balanced (Upadhyay et al., 2021). This balance is the company's strength, strengthening the company's position in the market. Adopting a sustainable approach means not only considering the environmental impact, but also introducing social and ethical principles and economically sound models (Ali et al., 2023). Thus, assessing the sustainability of a system requires consideration of three dimensions simultaneously addressing economic aspects, environmental concerns and social concerns (Biedermann et al., 2022; Valdivia et al., 2021). Martins et al. (2020) state that the warehousing processes can be described as a sequence of actions oriented towards a common goal. Insufficient attention is often paid to the improvement of warehousing processes in the context of sustainability. Their impact on the company's efficiency and financial results is underestimated, and the impact on the environment is not enough taken into account (Biedermann et al., 2022; Jum'a et al., 2022; Valdivia et al., 2021). Inadequately organized warehousing processes in the company reduce productivity, employee motivation; damage the image, increase costs for inventory storage and management of material resources, energy, waste management, internal transportation, etc. Mourtzis et al. (2019) argue that warehouses are one of the most important components of a manufacturing company, having considerable importance in the entire chain of the system. Innovation and sustainability-oriented solutions influence how efficient warehouse work is organized, the level of customer service, the timely delivery of raw materials to production workshops, the level of warehouse costs, customer satisfaction with the fulfillment of orders and the speed of the orders themselves (Olaku et al., 2021). However, mistakes in the warehouse cannot be avoided. One of the biggest problems faced is inaccurate inventory information. Assis et al. (2024) and Malinowka et al. (2018), point out that warehouse management and operational efficiency depend on quick search for goods, which sometimes becomes impossible—the search depends on the ability of warehouse workers to remember the places where goods are placed. Undefined responsibilities of warehouse workers, not properly prepared warehouses for the work, unused opportunities of IT and other innovative tools have a negative impact on the efficiency of warehouse processes, and at the same time on development of sustainability.

A considerable amount of scientific research is devoted for the improvement and analysis of warehouse processes. The importance of warehouse location in logistics was analyzed by Chiang et al. (2021), Martins et al. (2020), Marchuk et al. (2020) and other researchers. Adeodu et al. (2023), Tamas et al. (2017), Yener et al. (2019) and other authors studied methods of increasing the efficiency of warehouse operations. Analyzing the warehouse processes, researchers highlight the importance of innovative solutions in the warehouse processes seeking sustainability. According to

Assis et al. (2024), Machado et al. (2019), Zoubek et al. (2020) and others the implementation of technologies in warehousing processes is extremely important, since scientific and technical progress in warehousing logistics and innovation achievements are important in increasing the productivity of warehouse operations. Machado et al. (2019) studied the digital readiness of a set of manufacturing industries and proposed an application the Cyber-Physical-System (CPS), the Internet of Things and Big data Datasets. Zoubek et al. (2020) suggested taking into account technologies, processes and people, emphasizing the new concept of Warehouse 4.0, including general Industry 4.0 warehouse applications. Gimelshtein et al. (2021), Kudelska et al. (2020) argue that in the modern world, the trend towards warehouse automation is an important and inevitable part of company development. According to Tubis and Rohman (2023), when companies use innovative solutions, the level of development in both warehouse activities and other company logistics solutions increases significantly. Adeodu et al. (2023), Chiang et al. (2021), and Zinchenko and Krasnoplachtova (2017), in their scientific studies discuss that technology implementation is necessary for companies with intensive turnover processes. Gutelius et al. (2019) Shanmugamani and Mohamad (2023), notice, that in order to increase the efficiency of warehouse operations, it is necessary to implement technologies.

Although various scholars have previously studied sustainability-oriented solutions, there is still a lack of research related to innovative solutions for the improvement of warehousing processes towards sustainability. The objective of this article is to present potential innovative solutions for the enhancement of the warehousing process in a sustainable manner, from both theoretical and practical perspectives, with a focus on manufacturing companies. Consequently, this article concentrates on the existing literature pertaining to the warehousing processes and the identification of problems in manufacturing companies with regard to sustainability. This study presents a summary of the main findings and proposes potential innovative solutions that manufacturing companies could adopt to achieve sustainability. The originality and value of the article is based on the developed theoretical model and the obtained results, which reveal the manifestation of innovative solutions in warehouse processes towards sustainability.

2. Theoretical background

The theoretical background of this study covers the concepts and theories for seeking deeper knowledge about warehousing process and its integration with sustainability. In addition, the major objective of this theoretical framework is to have a basis to the analysis and to support key findings.

2.1. Features of warehousing processes

Zaman et al. (2023) argue that warehouses are not only a place of storage, but also a center of benefit. Identifying problems with warehousing processes is important for the company's profitability. Therefore, understanding their design and management principles plays an essential role in improving operational efficiency, reducing employee turnover and improving customer service levels. Saderova et al.

(2020) note that warehouses are supply chain regulatory elements that direct and transform material flows, and perform tasks that increase the value and availability of products. As a global interest of sustainable practices is recognized, companies should be encouraged to adopt innovations of sustainable supply chain (Guimarães et al., 2022).

Despite the variety of warehouses that exist today, which mostly differ in terms of size, type, functions performed, ownership and location, warehousing processes of manufacturing companies by researchers can be detailed into 6 processes, i.e., ordering of raw materials, their reception, transportation, storage, collection and loading of orders for finished products (Mourtzis et al., 2019; Tamás and Illés, 2017; Shanmugamani and Mohamad, 2023). There is no doubt that the accuracy and efficiency of the warehousing processes respectively determine the efficiency of the production company. Zaman et al. (2023) state that warehousing, as a process is an activity related to the warehouse of inventory and the management of warehouse space. To ensure the efficiency of warehousing activities, the arrangement of warehouses, the layout of premises, the type and safety of stocks, and ensuring the qualification of personnel are important. The implementation of warehouse processes depends on the main tasks of the warehouse, the structure and size of customer orders, and the warehouse location. Gimelshtein et al. (2021), Shanmugamani and Mohamad (2023) and others note that the warehousing process depends on the right strategy, warehouse layout, operations and material handling systems. In the scientific literature, the importance of efficient management of warehouse processes is also highlighted (Dede and Çengel, 2020; Mubarik et al., 2022; Tubis and Rohman, 2023; Zoubek et al., 2020). According to scientists, one of the most important goals in warehousing processes is to ensure that the right product is found in the appropriate, amount, at the proper time and intact. As a result, it is very important to manage the warehouse processes effectively so that all the listed criteria are met, because the transportation and distribution processes are a continuation of the warehouse processes, a small problem in the warehouse processes affects the entire logistics service (Dede and Çengel, 2020; Mubarik et al., 2022). In manufacturing companies, the use of warehouse management systems helps to achieve high profitability of warehouse operations, as well as long-term competitive advantages in realization and development and contributes for the improvement of sustainability (Sadia et al., 2022). In the scientific literature, rational organization in warehousing processes is also actualized, because only a rationally managed process guarantees stock safety, speed of operations, reduces costs and provides high-level logistics services and can be useful for the improvement of sustainability (Putra et al., 2020; Wulf et al., 2019). Improvement of warehousing processes ensures rapid availability of results using existing equipment (Assis et al., 2024; Husár and Knapčíková, 2021; Wahyuni et al., 2022). According to Shanmugamani and Mohamad (2023), Škerlič et al. (2017), all reorganizations, investments and technological changes in warehousing processes should be analyzed in a multifaceted way, and the most important thing is to identify problem areas. Tamas et al. (2017) and Wahyuni et al. (2022) indicate that the analysis of the warehousing process is one of the main steps to identify problem areas, which can be eliminated to ensure the smooth operation of the warehouse, the constant turnover of stored goods, and the maximum use of warehouse space. Integrating innovative solutions in the

warehouse eliminates errors caused by the human factor and shortens the time of operations.

2.2. General problems of warehousing processes in manufacturing companies towards sustainability

In the scientific literature (Gimelshtein et al., 2021; Martins et al., 2020; Machado et al., 2019; Olaku et al., 2021; Wahyuni et al., 2022) the following main problem areas of warehousing processes are distinguished: lack of space in the warehouse, lack of employees, insufficient work productivity, problems of inventory traceability and service level problems. Lack of space is influenced by poor inventory and procurement management, insufficient integration between financial and warehouse management systems, lack of designated specific warehouse locations for goods, high excessive amount of stock held, problems with receiving goods, not using ABC classification (Asana et al., 2020; Jemelka et al., 2017), inefficient warehouse layout (Albert et al., 2023). When solving the problems of lack of space in the warehouse, it is appropriate to review and improve procurement procedures, include the warehouse in procurement planning, implement innovative IT solutions, optimize balances and flows of goods and orders. The problem of low work productivity in the warehouse may arise due to the human factor and the specifics of warehouse. Human factor errors include employee turnover, lack of employee qualifications and motivation, and suboptimal use of resources (Rajnai and Kocsis, 2017). Overloaded warehouses, inadequate equipment, and inefficient use of resources and unreasonable demands of employees and/or customers can cause errors in warehouse specifications. To solve these problems, Gareis et al. (2021), Tubis et al. (2021) recommend accurate process definition, optimal work organization and process automation. Another problem arising in warehousing processes is the lack of workers. This problem arises due to the real market situation, lack of employee motivation, inefficient resource management and wrongly delegated functions to employees. The problem of the lack of employees could be solved by retaining existing employees by applying various motivational measures, attracting employees from other countries, as well as improving and automating warehouse processes. Inventory traceability problems arise in the presence of strict requirements and inaccuracy of product balances in the warehouse. Nallusamy et al. (2017) discussed the most common problems encountered in warehouses in his research. One of the problems is accidental overstocking due to poor workflow organization. Other scientists also identify this problem in their scientific works. According to Zasadzien and Žarnovsky (2018), the mentioned problem is caused by the human factor and increases labor and time costs, and this problem is more common in large warehouses. A separate group of problems includes poor preparation for seasonal stock needs (Putra et al., 2020; Wahyuni et al., 2022). A sudden surge in demand for goods can cause a lot of damage, as the warehouse may not be ready to accept orders. This can happen because there is not enough inventory in the warehouse or there is not enough space to store the inventory for a short time period. Problems are also caused by improper order of management, excessive costs for employees' wages and inadequate damage control (Aravindaraj and Chinna, 2022).

In conclusion it can be said, that the goal of the warehousing processes of

manufacturing companies is to create an efficient storage system toward sustainability. After analyzing the scientific literature, the definition of sustainable warehousing could be formed that it is a set of company activities and technological solutions aimed at effectively improving warehousing processes, maintaining the highest social standards, minimizing the negative impact on the environment in terms of financial efficiency (Aravindaraj and Chinna, 2022; Malinowka et al., 2018; Phan and Ali, 2021; Sadia et al., 2022; Wahyuni et al., 2022). Properly organized warehousing processes determine the performance and financial stability of the entire logistics system and the entire production company. Since the processes are interrelated and complement each other, the improvement of one or more operations in the processes will affect the efficiency of the entire warehousing processes in the context of sustainability. This proves the need for innovative and modern solutions. In the next chapter of this article, the authors present an application of innovative solutions in warehousing process towards sustainability.

2.3. Application of innovative solutions in warehousing process towards sustainability

Accelerating information flows, the continuous process of globalization, scientific progress determines the constantly changing conditions of the business environment and at the same time encourage business companies to look for innovative solutions towards sustainability.

In the scientific literature can be find various possibilities for the improvement of the warehousing processes. For example, by implementing the right warehouse management system (WMS) and optimal equipment in the warehouse, reviewing the warehouse processes and reducing human errors, these problems can be solved (Wahyuni et al., 2022). Mingxing et al. (2018) argue that WMS plays an essential role in warehouse and is the core of automated warehouse. It combines software and hardware; WMS implements automated inventory storage. Such data of management gives for company competitiveness and creates added economic value. It should be noted that implementation of modern WMS would contribute to the supply of better-quality storage services and the development of sustainability. It is also proposed to apply the JIT (Just in Time) inventory management system (Mankazana and Mukwakungu, 2018). Chaves and Pimentel (2023) debate that the aim of this system is to reduce the number of stocks. The application of the JIT method allows the acquisition of inventory only when the order is received and the product is immediately delivered to the customer. Dodrajka (2021) states that by correctly organizing the JIT system, it is possible to ensure the supply of raw materials directly to the production workshop and avoid additional storage. Another method discussed in the literature for the improvement of warehousing processes is Material Requirement Planning (MRP). Malindzakova et al. (2022) indicate, MRP parameters that affect inventory value are production type, storage level determination, consumption, lot sizing, procedure safety stock, forecasting strategies and item and product analysis. MRP is a precise procedure of requirements determination that is carried out under a demand program where planned market demands are in the form of warehouse requisitions. MRP works according to a logical scheme that allows

standardization of the warehouse process and eliminates ordering errors (Najy, 2020).

Management of logistics and warehousing processes is a rapidly changing field. Therefore, to achieve sustainability, further increasing the efficiency of warehousing processes is impossible without process tracking with modern and innovative technologies. Innovative solutions link the protection of natural systems with the concept of business innovation, while strengthening the processes of providing and storing goods and services that serve the goals of human health, justice and environmental justice (Biedermann et al., 2022; Pastoors et al., 2017). Phan et al. (2021) note that the market describes a contrast between customer requirements and technological possibilities. Innovative solutions and new technologies should be adapted for the improvement of sustainability first, and then to satisfy customer needs. Innovative solutions provide an opportunity to develop and increase the efficiency of warehousing processes and remain profitable and competitive in the market. Čolaković et al. (2020) indicate that companies invest in innovative technologies in order to gain a competitive advantage, maintain their positions in the market and generate additional profits. Efficient warehouse processes are unthinkable today without modern innovative technologies and solutions. This is determined by the active development of the domestic and global markets, as well as the rapidly developing warehouse infrastructure and growing requirements to achieve sustainability. Marchuk et al. (2020) state that modern warehouses include many interacting and complementary elements of the logistics system that provide storage of goods, processing and distribution functions among end users. The latest advances in artificial intelligence and automation and the ever-increasing capabilities of smart devices have created completely new conditions for revolutionary changes in creating and adapting promising global trends. As a key element of the Internet of Things, QR code is becoming increasingly important for online and offline services. When it comes to efficient warehousing processes and logistics, the focus should be on how quickly and accurately recognize QR codes (Čolaković et al., 2020; Chen et al., 2019; Jarašiūnienė et al., 2023).

After summarizing the analysis of the scientific literature **Table 1** presents innovative solutions for the improvement of warehousing processes seeking sustainability.

Table 1. Innovative solutions for improving warehousing processes towards sustainability.

Authors	Innovative solutions and description	Advantages
Adams et al. (2016); Albert et al. (2023); Aravindaraj et al. (2022); Azadeh et al. (2019); Berkers et al. (2023); Gimelshtein et al. (2021); Kudelska et al. (2020); Tubis et al. (2021)	Automatization and robotization. Warehouse robots are used to automate warehousing processes (e.g., pallet wrapping robots, sorting robots, mobile robot carts, rack structures, etc.)	• Removes errors. • Reduces defects, accidents, energy consumption. • Increases the efficiency of warehousing processes. • Increases productivity, reduces costs.
Chen et al. (2019); Giuffrida et al. (2021); Jemelka et al. (2017); Mingxing et al. (2018); Yener et al. (2019).	Big Data Datasets. Efficient processing of structured and unstructured massive analytical data from different sources at high-speed using scalable software tools for further apply of their effectiveness.	• Reduction of people's participation in decision-making. • Continuous self-learning process for optimizing business processes in the warehouse. • Analysis of results and implementation of necessary changes (forecast of demand fluctuations, determination of seasonality, adjustment of processes in the warehouse and others).
Albert et al. (2023); Aravindaraj et al. (2022); Giuffrida et al. (2021); Jarašiūnienė et al. (2023); Jemelka et al. (2017); Mingxing et al. (2018); Phan et al. (2021); Tijan et al. (2019).	Blockchain. Used for risk management, IoT (including logistics management using RFID, smart grids, etc.). It is characterized by data decentralization, ensuring a higher level of data security.	• Ensures data security, reliability, traceability and authenticity. • Visibility of the operational status of processes and timely decisions based on reliable data. • Helps reduce delays, overhead and human error.
Adams et al. (2016); Aravindaraj et al. (2022); Azadeh et al. (2019); Husar et al. (2021); Phan et al. (2021); Tijan et al. (2019).	Barcode Identification Systems (RFID). Using of radio waves for recording and reading information stored on labels attached to the product.	• More control. • More accurate inventory traceability. • Simplification of stock inventory. • Reduction of theft.
Chen et al. (2019); Mingxing et al. (2018); Phan et al. (2021); Tijan et al. (2019); Yener et al. (2019).	Electronic Data Interchange (EDI) technology. Enables automation of the sending, creation, processing, and receiving of any electronic data and to integrate them with existing business applications between computer systems and client's in the structured digital form.	• Enables significant acceleration of document management processes. • Increases sales to retailers and purchases from suppliers. • Human error is reduced. • Reduces inventory. • Optimizes product transportation routes.
Aravindaraj et al. (2022); Berkers et al. (2023); Tubis et al. (2021); Tijan et al. (2019); Vichitkunakorn et al. (2024).	Drones. Automated drones that can reach goods in a warehouse at high altitudes where other types of transport cannot. The real application area for drones is in stock inventory.	• Flexibility to store goods at height. • Reducing the time required for stock inventory.

Table 1. (*Continued*).

Authors	Innovative solutions and description	Advantages
Adams et al. (2016); Aravindaraj et al. (2022); Čolaković et al. (2020); Chen et al. (2019); Jarašiūnienė et al. (2023); Tijan et al. (2019).	Internet of Things (IoT). Provides the ability to maintain communication between sites or rooms and control warehousing processes, productivity, energy consumption, track inventory, improve customer service and efficiency.	• Management of business processes in real time. • Ensuring security. • Increasing the efficiency of warehouse equipment. • Implementation of successful business models. • Improving the quality of customer service and reducing risks due to unforeseen circumstances.
Gimelshtein et al. (2021); Mingxing et al. (2018); Shams-Shemirani et al. (2023).	Cross-docking. The process of receiving and sending goods through the warehouse without stocking in the long-term warehouse area.	• The costs of processing goods are reduced. • Minimum period of goods being in stock. • The turnover of warehouse space is growing. • Reduction of warehouse costs.
Gimelshtein et al. (2021); Husar et al. (2021); Mingxing et al. (2018).	Multi-storey warehouses. Consists of a multi-storey structure, where access to the floors is usually organized on a ramp, which provides the opportunity to divide the warehouse area into separate warehouses.	• Low operating costs. • Reduces shipping costs and shortens delivery time. • Possibility to use the entire modern infrastructure complex.
Bahr et al. (2022); D'Eusanio et al. (2019); Kumar et al. (2019); Ponis et al. (2020).	Digital training solutions. Today's warehouse employees are used to the ease and interactivity of using they associate with their mobile phones and other smart devices, and they respond positively to digital training.	• A modern and harmony-oriented workplace.
Bahr et al. (2022); D'Eusanio et al. (2019); Khan et al. (2024); Kumar et al. (2019); Ponis et al. (2020).	Gamification. Engaging the workforce through interactive and motivational productivity approaches: such as games or digital tools to improve the competence and productivity of warehouse workers.	• Real-time skills development for employees that inspires and guides them to achieve better results. • Encourages healthy competition for higher job positions and makes repetitive tasks more interesting and interactive.
Giuffrida et al. (2021); Jarašiūnienė et al. (2023); Mingxing et al. (2018); Phan et al. (2021).	Cloud computing. It is an opportunity to use the necessary IT resources after disconnecting them from a physical location, gaining access to them via the Internet. (e.g., cloud warehouse servers), for which a monthly fee is paid to the supplier).	• Increases the efficiency of warehousing processes. • Increases productivity, reduces costs.

Source: Authors' elaboration.

When discussing innovative solutions in the warehousing processes in order to achieve sustainability, it should be mentioned, that a social sustainability is no less important. Along with environmental sustainability, social sustainability is a major theme in warehouse trends. A competitive labor market and high employee turnover have forced warehouses and third-party logistics companies to focus on warehouse employees as core business lines. Social sustainability is about how effectively leaders empower workers and provide them with the knowledge and skills they need to be successful, making employees less likely to quit or be fired (D'Eusanio et al., 2019; Kumar et al., 2019). Constantly hiring and training new employees is expensive, and social sustainability is an incredible tool to reduce labor costs and increase productivity.

2.4. A theoretical model for the improvement of warehousing processes towards sustainability

The generalized and summarized analysis of scientific literature, presented in literature review part, enabled the authors of the article to establish a theoretical model revealing the improvement of warehousing processes with innovative solutions toward sustainability (see **Figure 1**).

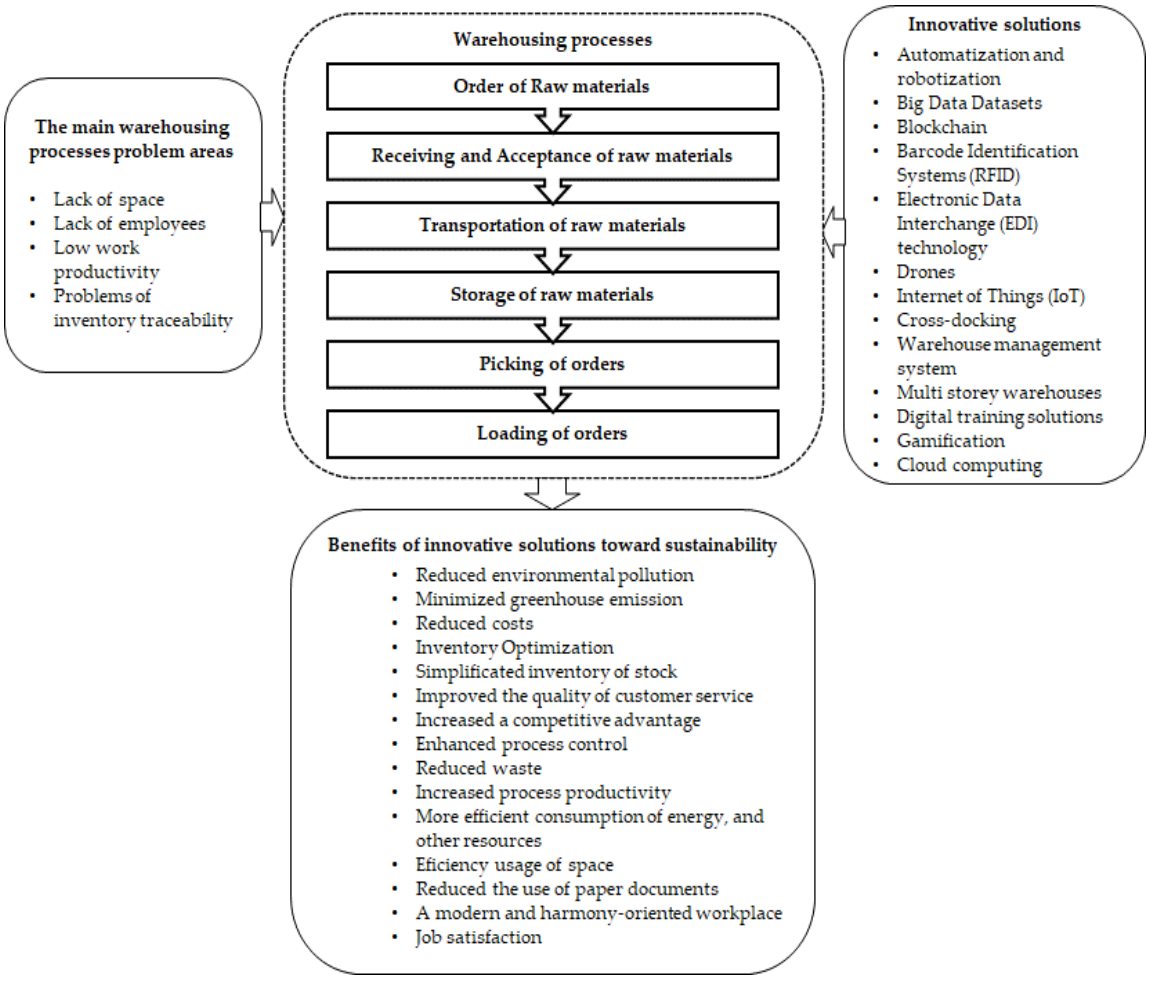

Figure 1. A theoretical model for the improvement of warehousing processes towards sustainability.
Source: Authors' elaboration.

The presented model reveals that 6 main storage processes such as: order of raw materials, receiving and acceptance of raw materials, transportation of raw materials, storage of raw materials, picking of orders, and loading of orders are traditionally distinguished. When carrying out these warehousing processes, problems usually arise due to lack of space and employees, low work productivity, problems of inventory traceability. Problems arising in warehousing processes can be solved by applying a whole series of innovative solutions related with the improvement of sustainability detailed in the model. Benefits of implementation of innovative solutions in warehousing processes towards sustainability can be visible through an economic (e.g., reduced costs, increased a competitive advantage, increased process productivity, etc.), social (e.g., a modern and harmony-oriented workplace, job satisfaction, etc.), and environmental aspects (e.g., reduced environmental pollution, minimized greenhouse emission, etc.).

Summarizing the information presented in this chapter, it can be concluded that the need of innovative solutions for the improvement of warehousing processes is obvious, because the capabilities of the human factor have reached the limit. It should be noted that inventory management with robotic systems eliminates potential errors and accidents and simplifies most warehousing processes. The integration of software and hardware solutions for effective accounting and management of key warehousing processes accelerates warehousing processes, reduces routine work volumes and increases staff efficiency. Also, should be remarked, that the most important thing of applying of innovative solutions is that warehouse will contribute to the development of sustainability, because energy will be used more intelligently, will be reduced the carbon footprint and waste of resources, also will be improved the safety of employees, etc.

3. Methodology

In order to disclose the application of innovative solutions in warehousing processes towards sustainability an empirical study was conducted in manufacturing companies of Lithuania. The methodological setup of the study consists of four steps. These steps include choice of research method, identification of participants and formation of research questions, data collection, analysis and evaluation of interview data (see **Figure 2**).

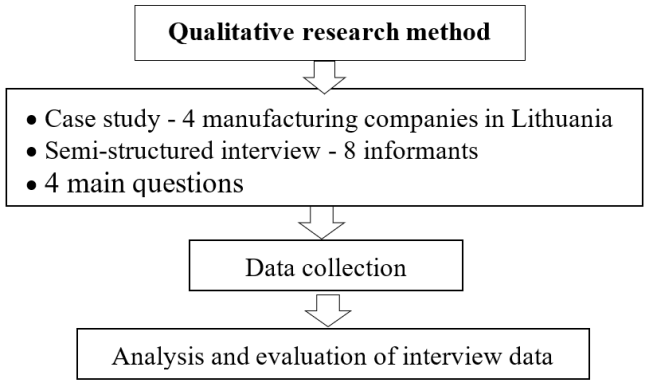

Figure 2. Logical schema of the empirical study.

Source: Authors' elaboration.

3.1. Research design

In this study was applied a qualitative research method. The basis of the qualitative method is open-ended questions, which are expected to be as broad, comprehensive and open as possible, formulated and presented by the research participant himself/herself (Austin and Sutton, 2014; Žydžiūnaitė and Sabaliauskas, 2017). An exploratory interview is defined as a researcher-initiated two-person interview aimed at gathering the information needed for research tasks (Austin and Sutton, 2014; Žydžiūnaitė and Sabaliauskas, 2017). The objectives of qualitative research are focused on details, nuances or processes, so the choice must be careful, considered and justified. It is appropriate to have a smaller number of research participants, so that each case can be examined deeper, and such participants are needed, whose special characteristics allow the best reflection and information about the research phenomenon (Miles et al., 2019). It is important to assess how many respondents it is appropriate to survey, because the reliability of the data directly depends on the selection of suitable respondents and the collection of sufficient data (Miles et al., 2019). The article examines 4 Lithuanian manufacturing companies, which were chosen for the study due to their experience in the market, which use advanced warehouse management methods in their operations. A semi-structured interview was chosen for the empirical study with 8 persons holding managerial positions in manufacturing companies, who are responsible for warehouse work, also have extensive experience in the management of warehousing processes, understand problems in the warehousing processes, and at the same time they are open to innovative solutions and ideas towards sustainability.

Based on scientific literature review and presented theoretical model (see **Figure 1**), were formulated 4 main questions to find out:

1) What are the biggest problems in warehousing processes?
2) What are the main causes of problems in warehousing processes?
3) What innovative solutions are applied in warehousing processes towards sustainability?
4) What are the benefits of innovative solutions towards sustainability?

3.2. Data collection

The semi-structured interview was conducted verbally (phone call, face-to-face) after arranging an acceptable time. All research participants were introduced to the purpose of the research and all questions raised by the participants were answered. The investigation is conducted based on the respect principles of personal privacy, confidentiality, benevolence and justice. Participants of the research had the opportunity to decide whether to participate in the study. Efforts are made to maintain an equal relationship between research participants and the researcher. An interview questions are prepared in such a way as to reveal the point of view of the research participants, not to mislead or impose the opinion of the researcher. The interview is conducted anonymously so that research participants feel safe expressing their opinions. The responses were recorded and later transcribed. Each interview took about 30–45 min. The study was conducted in 2023 in September–November. To preserve anonymity, research participants are coded I1, I2, ..., I8. Data is coded using

a qualitative content analysis method (Austin and Sutton, 2014; Žydžiūnaitė and Sabaliauskas, 2017). Therefore, using the content analysis method, the main goal was to select, sort, systematize, and analyse information by topic.

Interview method and analysis of the results helped to assess more broadly the warehousing processes in manufacturing companies, to identify their problematic aspects and to offer innovative solutions to achieve not only the efficiency of the processes, but also for the development of sustainability.

4. Results

At the beginning of the research, it was aimed to find out what are the biggest problems and their causes in warehousing processes. After evaluating the responses of the interviewers, 4 subcategories were distinguished: 1) lack of space, 2) insufficient work productivity, 3) lack of employees, 4) problems of inventory traceability (see **Table 2**).

Table 2. The main problems and their causes in warehousing processes in Lithuanian manufacturing companies.

Theme	Subtheme	Statements
Problems in warehousing processes and their causes	Lack of space	<…with a significant increase of orders, not only the amount of stored goods increased, but also the amount of raw materials and packaging required, there is a physical lack of space> (I1 and I2); <...the amount of stored raw materials and goods increased, the need for storage space increased accordingly...> (I3, I4); <…the current layout and equipment of the warehouse does not allow the full use of the height of the warehouse...> (I5 and I6); <...growing orders force to stock up on a larger amount of inventory, which is not always optimally arranged...> (I8); <… the amount of goods and raw materials increased due to inappropriate procurement procedures and procurement planning, as well as due to insufficient use of IT tools...> (I7).
	Insufficient work productivity	<…it is difficult to trace the location of raw materials because warehouses are overloaded> (I1; I3); <…currently not quite suitable equipment in stock> (I2; I4); <…there is a lack of more modern equipment when carrying out internal transportation or loading orders...> (I7); <...due to the lack of workers, unqualified workers have to be hired, and they lack interest in working> (I6); <…employees have little involvement in the work of the warehouse, they come to work for hours without thinking about the process or how it can be improved> (I5, I8).
	Lack of employees	<...the turnover of employees in the company's warehouse is quite high> (I1); <…work in sub-zero temperatures, so it is very difficult to find workers who want to work in such conditions> (I2; I3); <...work in warehouses is relatively difficult, some positions require special preparation, appropriate qualifications> (I4; I5; I6); <…it is increasingly difficult to find motivated employees> (I7; I8).
	Problems of inventory traceability	<… in the currently used systems, balances are often not accurate and their traceability in the warehouse is very problematic> (I1; I3); <...the lack of management systems complicates the control of stocks, their quantities> (I2; I4); <…employees do not know and do not find the place of deployment of supplies, make mistakes...> (I5; I7); <...currently we do not have an effective data management system, stock inventory is very complicated, employees waste a lot of time> (I6; I8).

Summarizing statements of the informants', it can be argued that the main problems in warehousing processes in Lithuanian manufacturing companies are related with 1) the lack of space in warehouse; 2) the insufficient work productivity; 3) the lack of employees; 4) the problems of inventory traceability. The informants pointed out that the lack of space in warehouse includes such aspects as the number of raw materials and packaging required. They also mentioned that there exists a physical lack of space, the amount of stored raw materials and goods increased. According to the opinion of interviewers' problems cause growing orders force to stock up on a larger amount of inventory. The current layout and equipment of the warehouse does not allow the full use of the height of the warehouse and the amount of goods and raw

materials increased due to inappropriate procurement procedures and procurement planning. The participants of the research are certain that the insufficient work productivity depends on overloaded warehouses, the lack of modern equipment and employees, as well as on the low involvement of employees in the warehouse work. The informants emphasized that the lack of employees depends on a relatively high turnover of employees in the company's warehouse, low temperature in the warehouses, lack of special training, motivation and proper qualification of the employees. According to the opinion of the interviewees, the main problems of warehouses traceability in the currently used systems are the inaccuracy of the balances in the warehouse, the lack of management systems, employee errors, the absence of an effective data management system, complicated stock inventory, high time costs.

In this research was also discussed the opinion of the informants about the implementation of innovative solutions and benefits in their manufacturing companies towards sustainability. This category was divided into four sub themes: 1) IT and other technological solutions; 2) Automation/robotization; 3) Warehouse equipment and 4) Warehouse management system. See **Table 3**.

Table 3. Innovative solutions applied in warehousing processes and their benefits in Lithuanian manufacturing companies towards sustainability.

Theme	Subtheme	Statements
Application of innovative solutions and their benefits	IT and other technological solutions	<…the accounting of goods is carried out computerized by programs, but the marking in the warehouse is on paper..., we have a barcode system in the warehouse, but it is used inefficiently, so the amount of manual work and the probability of errors increases, additional time costs are required...> (I1; I3); <...while optimizing warehouse processes, we constantly update IT software...> (I2); <…IT is installed, operational and periodically improved…> (I4); <… radio communication terminals (RFT) are used in the warehouse, operating anywhere in the warehouse, and data is transmitted using a wireless network...> (I6; I8); <… we have Pick by Voice along with barcode technologies...> (I5); <…applied voice assistant technology makes work much easier for employees, they no longer have to look at the device screen and use the keyboard to enter or find information...> (I7). <…the RFID system is partially implemented…> (I6).
	Automation/robotization	<… the dispatch process is partially automated, as loading is done by forklifts…> (I1; I3); <… we have a palletizing-depalletizing industrial robot...> (I2); <…sorting, assembly lines, etc. in the warehouse automated, but still a lot of manual work...> (I4; I5); <...one fully automated storage room is equipped, which does not require any manual work and allows to save storage space...> (I6); <...we are planning to automate the transportation process, we are considering the purchase of a robot for picking orders, which would increase work productivity and efficiency, reduce errors, and at the same time the losses incurred by the company...> (I7); <...the available automated equipment requires only minimal human involvement, there is a possibility to prepare orders at night, which only have to be brought to the ramp in the morning...> (I8).
	Warehouse equipment	<...the construction of a new warehouse required too large investments, it was decided to build more racks, for solving the lack of space...> (I1; I3); <...we intend to purchase multi-story racks...> (I4, I5); <...we use various load lifting and transportation equipment, which is characterized by energy efficiency...> (I8); <…electric forklifts have greatly increased work productivity and also improved indoor air quality…> (I6).
	Warehouse management system	<...the data should be visible in a real time and is synchronized with the business management system "Navision" used in the company...> (I1; I3); < ...we plan to install a modern warehouse management system, because the currently used electronic data exchange technology is ineffective...> (I2); <…the universal Equinox warehouse management system VISION WMS is applied, which is a complete door-to-door solution…> (I4; I5); <…the Pickersim warehouse management system is applied, which helps to manage warehouse operations, optimize work processes and have accurate information in real time...> (I6; I7).

Informants indicated that they have a barcode system in the warehouse, but its use is inefficient. They also updated IT software which should be periodically improved, some analyzed manufacturing companies have radio communication terminals (RFT); also Pick by Voice along with barcode technologies, one analyzed company in warehouse using the keyboard to enter or to find information, also in one manufacturing company is partially implemented the RFID system. Automation/robotization solutions in the analyzed manufacturing companies include two essential things: partially automation of storage processes and still existing a large amount of manual work. The informants stated that forklifts carry out loading. In one analyzed company, they have an industrial pallet removal and unloading robot in the warehouse. The representative of another company noted partially automation of sorting in the warehouse. In one analyzed manufacturing company they have fully automated storage room. In the other two studied companies, there are plans to automate the transportation process and purchase an order collection robot, which would increase work productivity and efficiency. When discussing warehouse equipment, informants mentioned that they decided to build more racks in their warehouses, to solve the lack of space. Others intend to purchase multi-storey racks. A representative of another analyzed manufacturing company noted that they use various load lifting and transportation equipment that is energy efficiency. One interviewer noted that the electric forklifts used in their warehouse greatly increased work productivity and improved indoor air quality. When was asked about the Warehouse management system (WMS), some interviewees mentioned that data should be visible in a real time and is synchronized with the business management system and that "Navision" (WMS) is used in their company. Another participant of the research pointed that they are planning to install a new modern warehouse management system, because the currently used electronic data exchange technology is ineffective. One more participant of the interview mentioned that the universal Equinox warehouse management system VISION WMS is used in their manufacturing company, another informant claimed that the Pickersim warehouse management system is applied.

After analysis of the research results, it can be stated, that the problems such as lack of space in warehouses; insufficient work productivity, lack of employees and inventory traceability problems raised in the theoretical model have been confirmed. According to the answers of informants, noticed that innovative solutions such as IT and other technological solutions in warehousing processes in their manufacturing companies are insufficient and limited. Warehousing processes automation is partially; the use of robots is just in beginning level. The equipment of warehouses also only partially meets the needs of the warehouses, unresolved issues of lack of space and of employees. The insufficient work productivity according to the informants depends on overloaded warehouses, the lack of modern equipment and employees.

In summary, the application of innovative solutions toward sustainability in our analyzed manufacturing companies is in a basic level and such solutions have a direct impact on addressing environmental issues and reducing emissions, and at the same time contribute to the development of sustainability.

5. Discussion and conclusions

In today's changing world, a greater global focus is on more sustainability-oriented innovations (Pastoors et al., 2017). The rapidly growing of industry encourages manufacturing companies to constantly look for the innovative solutions that would increase the efficiency and productivity of warehouse operations, while at the same time ensuring compliance with the development of sustainability (Ali et al., 2023; Ries et al., 2016). As the flow of goods increases, all companies with warehouses are looking for ways to improve the warehousing processes, increase the efficiency and competitiveness of warehouse operations, and contribute to the development of sustainability. Currently, the area of warehouses of companies usually remains the same, regardless of the constantly growing amount of cargo. For this reason, various problems arise, such as long loading/unloading times of machines, downtime and delays in order reloads, disruption of work planning and efficiency of the entire warehouse. Warehousing processes must be properly organized, operations must be performed accurately and quickly, saving production and human resources. In order for the mentioned processes to be smooth, proper storage of raw materials and products must also be ensured. The operations of the warehousing processes of manufacturing companies are interrelated and complement to each other, so the improvement of one or more operations affects the efficiency of the entire warehousing processes and contributes to the development of sustainability. The common errors in warehousing processes, which have the most negative impact on the operation of the warehousing processes, are the reception of raw materials, storage and collection of orders. Sustainable warehouse management, using innovative and modern solutions, methods and tools, is one of the main business success factors of manufacturing companies (Čolaković et al., 2020; Chauhan et al., 2022). Software and automation tools would increase warehouse operational efficiency and at the same time develop sustainability (Munodawafa and Johl, 2018; Phan and Ali, 2021; Rey et al., 2021). Since the warehouse management system (WMS) plays an important role manufacturing companies should pay more attention to the planning and execution of logistics services (Mingxing et al., 2018), in order to achieve more efficient and sustainable warehouse operations. Therefore, for manufacturing companies recommended implementation of the latest and most suitable WMS in their warehousing processes. WMSs currently available on the market include cloud-based warehouse management system (Giuffrida et al., 2021). The advantages of this system are quick installation, no maintenance costs and lower IT costs. Integration with ERP (Enterprise Resource Planning), WMS integration is an important factor when the business model is difficult to manage and requires real-time system communication (Putra et al., 2020). In order to automate inventory planning and continuous monitoring of the storage process, it is appropriate to apply the MRP methodology (Malindzakova et al., 2022; Najy, 2020), based on the planning of the need for raw materials according to the production plan for a specific period. In this way, the storage and production processes linked, and the satisfaction of production needs ensured. Other innovative solutions for the improving the warehousing processes in manufacturing companies while developing sustainability are the Internet of Things (IoT) (Čolaković et al., 2020; Song et al., 2021), which are used to provide the ability

to maintain communication between sites or rooms and control warehousing processes, productivity, energy consumption, track inventory, improve customer service and efficiency. Barcodes and modern data processing technology should be used for all warehouse process operations to be performed quickly and accurately.

Our prepared theoretical model (**Figure 1**) for the improvement of warehousing processes towards sustainability and verified by applying the interview method in Lithuanian manufacturing companies allows to state that when improving warehousing processes in manufacturing companies for sustainability, the greatest attention should be paid to implementation of innovative solutions. Our findings suggest that warehousing processes can be improved by applying innovative technologies and methods, such as Multi-storey warehouses, WMS, Big Data Datasets, Blockchain including logistics management using RFID, smart networks, etc., Barcode Identification Systems (RFID), Electronic Data Interchange (EDI) technology, Drones, Robots, Internet of Things (IoT), Cross-docking, Cloud computing. The results of our study are similar to Berkers et al. (2022), Škerlic et al. (2017), investigation, since the search and application of innovative solutions can improve the design of warehouse systems, more efficient work of employees and at the same time to ensure a reasonable and balanced policy of automation of warehouse processes towards sustainability. In order to raise the qualifications of employees and possibly to solve the problems of lack of employees, it is proposed to apply a digital training solutions and Gamification while contributing to social sustainability. Similarly, with the help of the Gamification method, employees are involved in the work process by applying interactive and motivating productivity methods: such as games or digital tools aimed at improving the competence and productivity of warehouse workers (Khan et al., 2024; Ponis et al., 2020). Digital training solutions help to create a modern and harmony-oriented workplace (Bahr et al., 2022). Our research also shows that it is necessary to pay attention to the benefits of implementing innovative solutions in warehousing processes not only in terms of economic, but also social and environmental issues in order to achieve sustainability. In the theoretical model presented benefits corresponds to Wahyuni et al. (2022) statements that use of innovative solutions reduce energy consumption, costs, water consumption, minimize the environmental impact in each warehousing processes. Therefore, our research confirms Adams et al. (2016) conceptual model of sustainability-oriented innovation (SOI), according to which the application of sustainability-oriented innovations in the operational process not only yields economic returns, but also creates social and environmental value.

The findings of this study could be incorporated into policies and regulations to promote sustainable warehousing and logistics practices across industries. This could reduce carbon emissions, waste generation and resource consumption, ultimately benefiting the environment and society as a whole. The application of innovative solutions in warehousing processes can also have economic benefits, such as cost savings through increased efficiency and a better reputation among consumers who value sustainability. It also can increase the competitiveness and profitability of companies that adopt these solutions. Overall, the findings of this study can have positive effects on both the environment and the economy, making it a valuable contribution to the field of logistics and supply chain management.

The limitation of this work is that the chosen research method does not give completely representative results, because the qualitative interview based on open questions that are not broad and depend from the progress of the conversation during the interview. Another limitation of this study is that in order to provide as many innovative solutions as possible, it would be appropriate to use a quantitative data collection method to further explanation of the topic. We did not use this method due to the relatively large scope of the study, so the authors intend to develop this study in the future. The current stage of the study aims to verify the results of the scientific and interview analysis.

In addition, the authors aim to encourage other scientists and practitioners involved in the improvement of warehousing processes to have an open discussion this topic for innovative solutions for warehousing processes towards sustainability.

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