

Article

Improving the Information Systems of a Warehouse as a Critical Component of Logistics: The Case of Lithuanian Logistics Companies

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Abstract: Rapid changes in the modern world and technological advances and processes are increasingly contributing to greater attention being given to emerging problems associated with obtaining big data, as well as modifying decision-making processes in diverse spheres. Special attention in logistics companies should be given to the warehouse as a critical component of logistics, in particular to such processes as big data processing and automation, as well as the improvement, development, and support of information systems. Enhancing logistics information systems provides companies with a competitive advantage, reduces the emergence of human error, accelerates processes, and ensures the collection and sharing of information and big data are used in a sustainable manner. The automation of warehouse processes results in better-established operational safety and overall service quality. The present paper reviews the importance of improving warehouse automation and logistics information systems. Its advantages are highlighted, and the results of the conducted research are provided to expose the problem areas of warehouse automation and encourage improvements in information systems in Lithuanian logistics companies wherein there is a need to transfer a large amount of information and increase service quality.



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1. Introduction

Logistics companies must constantly observe market changes and respond quickly to consumer demands, as customer demands are becoming increasingly volatile and difficult to predict. Discerning consumers of logistics services are selecting companies that provide top-quality services only. Kihel [1] states that companies must adapt to changes in digitalization processes and big data whilst implementing their latest technologies and logistics information systems to achieve customer satisfaction and operational efficiency. In today's technologically changing economies, with growing supply of and demand for goods as well as with intensifying flows of such goods, companies must own warehouses to service their clients in a productive, fast, and cost-effective manner [2]. The digital and technological transformation of logistics services is responsible for changes in warehouse management and investment and systematic approaches towards employee training possibilities. According to Kihel [1], a warehouse should no longer be referred to as a simple

storage location for products and materials but rather as a strategic element of big data and information within logistics companies; thus, it is important to effectively manage information flows emerging from warehousing processes. Taletović [3] claims that a warehouse is the pivotal element in the supply and logistics chain. It stores, handles, and manages freight, goods, or materials prior to distribution or processing. According to Heriyanti & Ishak [4], to coordinate the flow of materials, finished products, and raw materials, it is necessary to deploy logistics information systems in a company. The objective of this paper is to carry out a feasibility study on the improvement of automation and logistics information systems within a logistics company, i.e., a warehousing service.

Zsifkovits et al. [5] observe that companies with greater financial and technological resources more often tend to be leaders in developing the latest automated technologies. Developing automated technologies is a necessary tool for logistics companies to ensure competitiveness, reduce manual labour, increase operational efficiency, and improve overall service quality. Although the benefits of automation are indisputable, small and medium-sized companies often lack the necessary knowledge and understanding of the latest technologies and their impact on business processes.

2. Warehouse as a Logistics Element

A warehouse is a pivotal part of logistics wherein important functions of the supply chain process are performed, such as storing raw materials, inventory, goods, and finished products [6]. Being an essential part of companies' activity and overall logistics system, the warehouse ensures a smooth link between the manufacturer and consumer by receiving and transmitting large amounts of data and information [7].

Warehouses are used to protect cargo from environmental factors and human activity [8]. Warehouses are necessary to maintain appropriate inventory levels, assist in the delivery of goods, and effectively manage logistics information systems. In their research, Andiyappillai [9] determined that to survive in a competitive market, a company must execute effective management of information flows in a warehouse. This requires effective management of warehouse information processes and the data stored in them. According to Kihel [1], currently warehouses are challenged by problems emerging from demand, digitalization, and big data dynamics processes.

Most often, information flows and big data are accumulated in a distribution warehouse. In this type of warehouse, the following activities are executed: receiving of cargo (from a central warehouse, factory, or supplier), storing of received cargo, preparation of cargo for distribution, consolidation and preparation for distribution, and distribution of cargo to consumers [10].

According to Wiyono [10], the distribution warehouse acts as a central warehouse, and their information management systems become particularly important. The processing of big data is also of great importance in transit and transshipment warehouses, where incoming cargo is received from one mode of transport, sorted by destination, and loaded on to another mode of transport [11]. Warehouses are classified according to their technological level in the logistics supply chain as manual, mechanical, and automated warehouses [11]. According to Lin & Li [12], it is necessary to automate processes in order to effectively manage warehousing processes. This requires an information system or computer to execute the operations of shipping and receiving of goods without manual human intervention. One of the advantages of the above-mentioned warehouse is that it can optimally utilize its space, time, and manpower to manage warehousing processes and includes such warehouse functions as storage, transportation, distribution, and management [12].

According to Wiyono [10], a warehouse is said to be appropriate if it can perform based on its functions. To achieve the function (Figure 1) of a warehouse, it is necessary

to design the right facility layout in accordance with the purpose of the warehouse. A warehouse should also be in a strategic location to ensure the smooth movement of goods and fast logistics processes. The warehouse should be easily accessible for both suppliers and customers, and at the same time, it should be located close to major transport hubs and highways to reduce transportation costs and time.

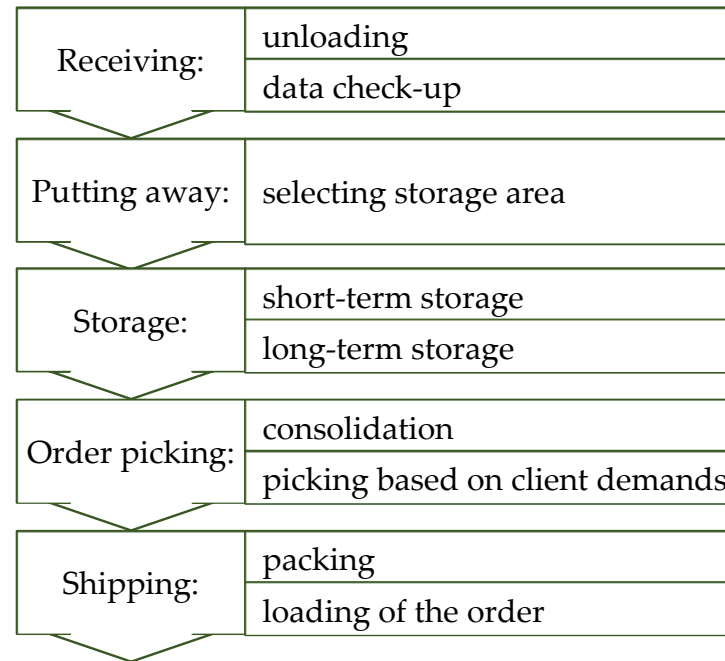


Figure 1. Warehouse functions. Source: developed by the authors, based on [13].

The first stage is the receiving stage, during which notifications on the arrival of the goods are received. An information system and accurate transmission of big data are required to create and format notifications. With the help of the information obtained, warehouse employees receive incoming cargo and efficiently perform the necessary activities, which are completed in the second stage. Received goods are marked and documented in the information system and prepared for storage. In this way, a clear system of stored goods is established, enabling staff to manage the flow of goods in the warehouse. The logistics information system facilitates the management of big data pertaining to inventory. It also enables the proper utilization of warehouse resources and preparation for further cargo processing.

Poor information processing or an outdated system can cause one of the most fundamental problems—inefficient processing of large data flows and, as a result, improper cargo storage [14]. Being mismanaged and processing a large amount of data means that the logistics information system assumes that goods are stored in any available warehouse space, which significantly prolongs the process of selecting and shipping the goods [14,15].

The third stage is storage, which is part of logistics activities that have a direct impact on the costs, operational efficiency, and service quality of a logistics company [16]. Proper management of the storage process can prevent damage or loss of goods, ensuring that customers receive quality and timely delivered goods. It is important that at this stage, the logistics information system contains information about the cargo stored in the warehouse [17]. Such information will enable employees to perform their assigned functions faster and more efficiently, to work more productively, to reduce cargo search time, and to increase overall operational efficiency. When warehouse processes are managed manually, it takes more time to process large information flows, there is a risk of human error, and paper documents used for information transmission violate the principle of sustainability

and negatively affect the cargo delivery process. Lengthier cargo loading and shipping processes reduce the efficiency of distribution resources, and they also increase the risk of cargo reaching the end user later [4].

3. Benefits of Automation in Logistics

During the automation processes of receiving or sending large flows of data, computer software or robots perform these tasks more accurately and thoroughly than human employees [18]. Automation makes it possible to reduce manual workloads and human errors [19]. It is possible to distinguish the following advantages of automation:

- the accomplishment of tasks that are complex and cannot be done manually;
- automated equipment being located in the areas that are dangerous to employees;
- lower labour costs;
- operations being more accurate;
- reduced lead times, as complex tasks are conducted in a fast and easy manner;
- mitigation of the effects of labor shortage [5,18].

By using automated solutions, operational efficiency is achieved, costs are reduced, service quality is improved, and manual labour is substantially minimized or eliminated [5]. In his account on automation's possibilities in logistics supply chain management, Nitche [20] claims that even though process automation is an important technological trend and interest in it will accelerate in the future, companies still have their doubts over whether to apply automated solutions in their activities. Nitche [20] emphasizes that automation is one of the most important changes in processing big data flows and managing logistics processes at all levels, from long-term strategies to daily operational activities. To reduce costs and occurring errors, increase efficiency, and not depend on individual employee decisions, companies must automate large information flows and physical processes. Dhaliwal [21] claims that major advantages of warehouse automation are fast-paced operations, efficient spatial planning, reduced probability of human errors, efficient data collection and sharing among different functional areas, and enhanced competitive advantage (Table 1). However, Tiwari [22] identifies disadvantages emerging from excessive cargo handling, when cargo is being moved, sorted, calculated, and prepared for storage or stored. These steps take a lot of time, as cargo is being handled a lot more than is necessary (Table 1).

Table 1. Advantages and disadvantages of warehouse automation.

Advantages	Disadvantages
Reduced operational costs; Enhanced operational safety; Fulfilling urgent orders at a fast pace Reduced manual labour; Efficient spatial planning of the warehouse; Reduced probability of human errors; Increased data collection and sharing; Enhanced competitive advantage.	Excess cargo handling; Outdated equipment in everyday operations; Inefficient spatial planning of the warehouse; Damaged cargo; Employees must allocate a great amount of time; Greater costs.

Source: developed by the authors and based on Dhaliwal [21], Tiwari [22].

The increasing strategic importance of warehousing in logistics encourages companies to strive for excellence in warehousing operations [23]. The growth of e-commerce and increased consumption are affecting logistics processes. Hopkins & Hawking (2018) and Krolczyk et al. (2020) link automation to consumer needs and opportunities for collaboration between other logistics companies [24,25]. Xiao et al. (2021) in their research stated that increased demand and new business directions are reorganizing logistics spaces [26].

The greatest emphasis is placed on the reorganization of logistics facilities, i.e., warehouses, to speed up the movement of goods throughout the supply chain. There is a need to build warehouses close to consumers. Such a need, according to Boysen et al. (2019), has developed a new generation of warehouses, which are adapted to retailers serving the end consumer using the B2C (business-to-customer) business model [27]. Such warehouses are characterized by a large and wide assortment of goods, fast and accurate delivery schedules, dependence on seasonality, discount packages, etc. The development of such B2C business models has a significant impact on both transport companies and warehouses in their cooperation with each other. According to Jain et al. (2021), the Internet has enabled the expansion of logistics collaboration, which also affects the automation of logistics processes [28]. During collaboration, according to Ramachandran et al. (2022), automation helps logistics companies to develop faster and increase operational efficiency, but increases operating costs, since the automation process itself is expensive [29]. Tejesh and Neeraja (2018) emphasized that the implementation of the system should not be a cause of very high costs, so they should be taken care of in advance, i.e., when choosing the system [30]. The system can monitor the number of products in real time, so its implementation should be accurate, and the accuracy of the system is one of the elements that make up the purchase price of the system. Another element that affects the price of the system is the flexibility and adaptability of the program (system) itself to the workplace. Such flexibility is given to individual tracking elements, but it should not disrupt the daily work rhythm of those working with this system, and it should be convenient for the user to use it. Investing in warehouse automation increases opportunities for companies during cooperation, which increases the productivity of companies. According to Cao & Jiang [16], modern companies encounter a great number of issues pertaining to market changes and growing competition; thus, to remain competitive companies must constantly introduce innovations and optimize processes. It is imperative to draw attention to eliminating faults in warehousing process, such as negative human activity, suboptimal utilization of space and volume, and high storage costs due to outdated equipment or warehouse structural defects. Warehouse automation reduces human involvement in supply, receiving and distribution, sales, and shipping tasks. It is mandatory to implement automated hardware and software infrastructure in warehouse operations [31]. Tiupysheva et al. [32] point out that warehouse automation is mistakenly associated with robots; however, in many cases, it may only be a matter of replacing manual tasks with software solutions. According to Andiyappillai [9], the warehouse management system (hereinafter referred to as the WMS) is a software, control and management system that automates logistics processes and optimizes warehouse operations. Alum & Kesen [23] state that the WMS helps to plan, optimize, and control all daily warehouse operations. To increase the flexibility and efficiency of the WMS, it can be integrated with diverse systems, sensors, and equipment. Thus, the implementation of an automated WMS system in warehouse operations is a key factor ensuring the successful development of the company [9]. Warehouse management systems are divided into the following three groups [33,34]:

- The basic WMS system is specifically designed to maintain inventory and location control. This type of WMS system is used to record, store and gather information on the goods.
- The advanced WMS system features the ability to carry out resource planning actions related to synchronized goods' flows in the warehouse. This type of WMS is oriented towards warehouse throughput, inventory, and capacity analysis.
- The complex WMS system is designed to organize and optimize warehouses simultaneously. In this type of WMS system, the functions encompass such processes as

transportation planning, planning of value-added logistics, and maintaining communication between different members in a supply chain.

Burinskienė and Lerheris (2021) emphasize in their research the efficiency of well-organized warehousing operations, including inventory accuracy, delivery accuracy, transportation control itself, and equipment management, which would not be possible without a WMS. WMS automation enables more efficient inventory management and faster production, as it allows for more efficient use of raw materials. By automating routine tasks, the WMS enables logistics companies to operate more efficiently and make more optimal decisions related to the company's operations using the analyzed data [35]. According to scientists Nitsche [20] and Alm & Kesen [23], warehouse automation can be performed using automated storage vehicles, autonomous mobile robots, and automated storage and retrieval systems (Figure 2). According to Nitsche [20], automation of physical and big data flows in logistics and supply chains is paramount. The objective should not be focused on automation but rather on gradually enabling these processes to operate autonomously with decision-making capabilities. Alm & Kesen [23] note that an automated system refers to machines that carry out predetermined tasks and are controlled by a computer, whereas an autonomous system enables machines to make decisions independently as they encounter new and unexpected situations.

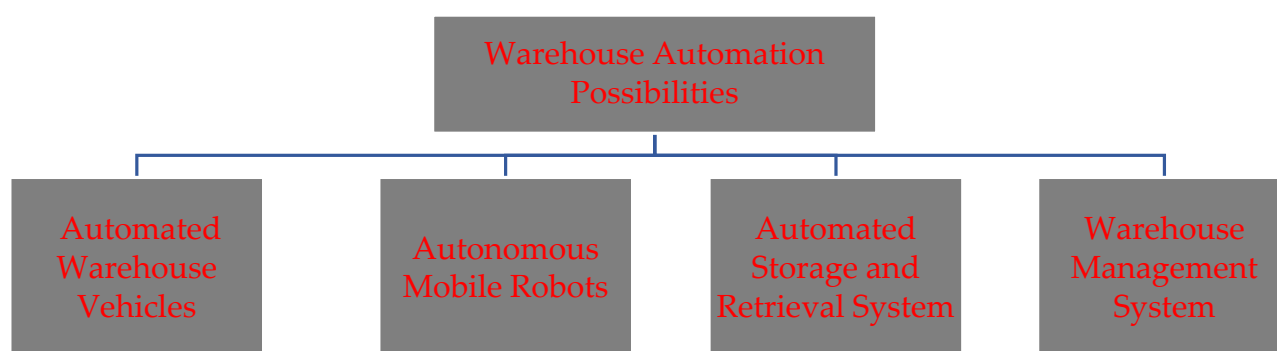


Figure 2. Warehouse automation possibilities (developed by Nitsche [20], Alm & Kesen [23]).

Although these are definitions with different meanings, autonomy is the final stage of automation [36]. Automated-guided vehicles (hereafter AGVs) are typically self-propelled, unmanned vehicles that transport and carry goods [37]. Although AGV systems have been known about for several decades, it was only with the development of the Industry 4.0 concept that companies began to take a broad interest in implementing them in logistics processes. According to Tubis & Poturaj [38], the implementation of AGVs involves significant investment in fixed assets. However, their use reduces companies' costs, considering the benefits that AGVs bring (Table 2).

Table 2. Benefits of warehouse automation.

Benefits	Authors
Increasing efficiency	[39] (p. 8);
Ensuring safety of labour and goods.	
Reducing operational time	
Increasing reliability and accuracy of packing and picking processes	
Helping companies improve forecasts due to the availability of accurate data	
Real-time data help with accurate decision making	
Enhancing the overall performance of companies	

Table 2. Cont.

Benefits	Authors
Lower maintenance expenses	[38]
The ability to work 24/7 with minimal labour and human intervention costs	
Increased logistics operations' productivity and the extension of the entire SC's service level	
Operations with advanced sensors, cameras, and AI algorithms	[23]
Adapting on a basis of the environment	
Automation of cargo transportation and picking processes	
Reduces manual work and order fulfilment time	[23]
Space utilization	
Reduced operational costs	
Reduced probability of human errors	[23]
Increased operational safety in warehouse processes	
Increasing efficiency	
Monitoring operational processes in real time	[9,23]
Speeding up the process of preparing and shipping orders	
More efficient resource management	
More accurate fulfilment of customer orders	[9,23]
Ensuring the successful transmission of information between divisions	
Sustainable document management possibilities	
Detailed digital recording of activities	

Source: developed by the authors.

Automated storage and retrieval system (hereinafter AS/RS) is a system that automatically stores and retrieves goods without manual processing [40]. It organizes, stores, and accurately sorts diverse cargo [41]. Alm & Kesen [23] draw attention to the fact that AS/RS installation and maintenance costs may be substantially higher compared to those of a conventional system. Once a system is successfully installed, it can be very difficult to remove it and make changes in the future. This system should be used in businesses that have regular and recurring operations. Autonomous mobile robots (hereinafter AMRs) are the latest and most innovative version of automated vehicles [21]. One of the main objectives of warehouse robotics is to ensure efficient navigation of autonomous equipment on warehouse premises [42]. Diverse methods are used for navigation; some devices require special markings on the floor or integrated sensors that allow artificial intelligence to recognize objects in real time and adapt to the environment.

A production logistics system connected to the Internet of Things can be used in various individual production sectors as well as in warehousing. According to de Vass et al. (2018) and Papatsimouli et al. (2022), the Internet of Things is a new generation of technologies that are connected to the Internet through embedded information and communication technologies and integrated into logistics activities in a digital environment [43,44]. The Internet of Things also involves the production of home appliances and automotive and electronics products. The main goal of the Internet of Things is to monitor and operate devices in real time. Their use allows data collection to be performed without human intervention.

In summary, it is possible to claim that market changes, growing competition, and manual labour contribute to problems emerging in warehousing processes, such as excessive cargo handling, outdated equipment in everyday operations, lack of mechanized processes, incorrect cargo placement, and slow working pace. To organize warehousing processes in a qualitative manner and remain successful in market, logistics companies must integrate automated logistics information systems.

The use of automated warehouse solutions increases companies' competitive advantage and revenue, minimizes costs and the need for manual labor, eliminates the probability of human error, enhances working pace and efficiency, and effectively utilizes warehouse space. Automated warehouses improve the quality of services and speed up big data processing. To achieve a greater competitive advantage, fewer errors, and higher profits, companies must strive to automate warehouse processes using innovative technologies, including automated storage and retrieval systems (AS/RSs), automated guided vehicles (AGVs), warehouse management systems (WMSs) and autonomous mobile robots (AMRs).

4. Research on Automation of Lithuanian Warehousing Companies and Research Methodology

Automated warehouse solutions enable the optimization of processes and autonomous management of logistics processes; thus, companies function faster, more accurately, and more economically by providing a long-term competitive advantage. There are certain factors that each company should consider before implementing warehouse automation technologies. To understand warehouse automation, an in-depth investigation is required. This investigation is to be carried out in the following stages (as shown in Figure 3). The first stage is dedicated to preparation. The operational specifics of a warehouse, as an element of logistics, are only known to the professionals involved in it, i.e., experts. A questionnaire is designed, in which questions are grouped in accordance with warehouse functions and automation processes in information systems; logistics experts who can fill in the questionnaire are sought out. The second stage involves expert questionnaires and data processing. The third stage, generalization, aims to summarize the data in order to draw certain conclusions pertaining to implementing further automation solutions in information systems to improve warehouse operations.

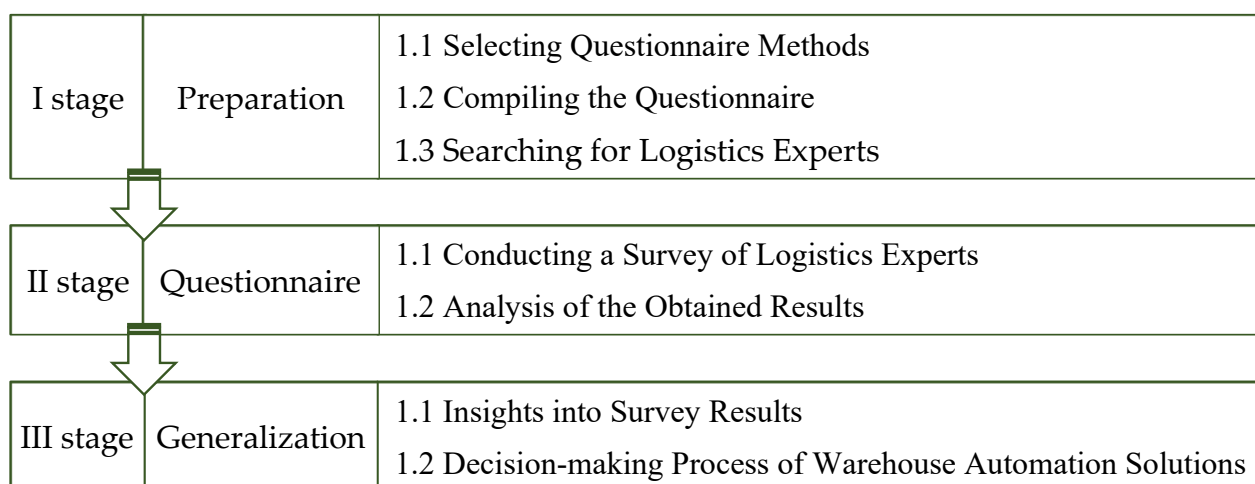


Figure 3. Research scheme (developed by the authors).

A great number of functions are performed in a warehouse, and the decision-making process is highly influenced by them; consequently, multi-criteria assessment methods are best suited to the purpose of evaluating alternatives. Data collection in multi-criteria assessment methods is carried out by means of a questionnaire survey aiming to clarify diverse approaches to technological solutions for logistics information systems and warehouse automation, their advantages and disadvantages, as well as emerging challenges. The questionnaire method enables statistical material, interactions, and dependencies among diverse phenomena to be collected [45]. Questions are used to rank responses. To obtain detailed information on warehouse automation processes, participating experts are expected

to fulfil the following criteria: 5 years of professional experience in warehouse operations and 10 years of continuous work-experience.

The warehouse automation research methodology must be reliable; therefore, one method cannot fully reflect the research results. Therefore it is important to be able to compare and connect results obtained from different methods to achieve a more accurate picture of the object under evaluation. Four assessment methods were chosen for this research: arithmetic, geometric mean, weighted sums (SAW—simple additive weighting), and expert data ranking and processing methods. The results of the weighted sum method, i.e., object ranking, differ very little from those of complex mathematical and statistical methods [46]. In their comparison of multi-criteria methods, Çalık et al. [47] pointed out that the weighted sum (SAW) method enables more accurate assessment of the results.

The arithmetic, geometric mean, and weighted sum (SAW—simple additive weighting) methods are best suited to comparing more than two characteristics or criteria. These methods are based on the idea that certain characteristics or qualities with higher values should be more important and carry more weight. The advantage of these methods is simplicity and transparency [48]. Their simplicity lies in the fact that criteria values for each selection can be easily compared. The method also allows for flexible changes in weight values, considering alterations in priorities.

The arithmetic mean method is carried out by selecting weights for each criterion w and taking into consideration the company's priorities in relation to the problem under analysis. Moreover, it is possible to select equal weights ($w = \frac{1}{n}$, where n is the number of criteria). Then, the results of each alternative are calculated in accordance with the Formula (1).

$$A_j = w_j \frac{\sum_{i=1}^n x_{ij}}{n}, \quad (1)$$

A_j —arithmetic mean, w_j —coefficient for alternative, x_{ij} —expert estimate of the specific alternative, n —number of alternatives, j —sequence number for the alternative, i —sequence number of the expert.

The geometric mean is calculated by multiplying all values and extracting the n th root. However, with multi-criteria methods, it is multiplied by the alternative weight coefficient in the final Formula (2).

$$G_j = w_j \sqrt[n]{\prod_{i=1}^n x_{ij}} \quad (2)$$

where G_j is the geometric mean, w_j is the coefficient for the alternative, x_{ij} is the expert estimate of the specific alternative, n is the number of alternatives, j is the sequence number for the alternative, and i is the sequence number of the expert.

The estimates of the weighted sum methods are calculated by summing the normalized estimates and multiplying them by the weight of that estimate or selecting equal weights ($w = \frac{1}{n}$, where n is the number of criteria), as in Formula (3).

$$S_j = \sum_{i=1}^n w_j x_{ij} \quad (3)$$

where S_j is the weighted sum, w_j is the coefficient for the alternative, x_{ij} is the expert estimate of the specific alternative, n is the number of alternatives, j is the sequence number for the alternative, and i is the sequence number of the expert.

The indicators are normalized, i.e., the maximizing indicators are transformed according to the following formula:

$$w_{ij} = \frac{m_{ij}}{\sum_{j=1}^n m_{ij}} \quad (4)$$

where w_{ij} is the normalized value of the indicator of criterion (i) for the j th alternative, m_{ij} is the value of the indicator of criterion (i) of the i th alternative, and $\sum_{j=1}^n m_{ij}$ is the sum of the values of the indicators of the indicators in the i th criterion for the j th alternative.

The concordance coefficient is used in the multi-criteria assessment. Should the value of the concordance coefficient be close to one, then the expert assessments are not considered to be contradictory, and the consistency of assessments is considered sufficient. If assessments differ substantially, and values are close to zero, then it is advisable to carry out an additional assessment.

Ranking is a procedure in which the most important indicator is given a rank of R that is equal to one, the second indicator is given a second rank, and the last indicator is given a rank m (where m is the number of benchmarks). Expert assessments obtained from the completed questionnaires are presented in the table below. Based on the multi-criteria evaluation method, the evaluations constitute a matrix of n rows and m columns and are listed in Table 3 [49]. Based on the methodology, the expert group n quantifies the object m . The evaluation can be fulfilled in indicator units, unit fractions, or percentages, or in a decimal system. The ranking of expert indicators is suitable for calculating the concordance coefficient. The concordance coefficient indicates the level of compatibility within the expert group should the number of experts exceed two.

Table 3. Matrix of evaluation indicators (developed by the authors according to Sivilevičius 2011).

Expert Code		Indicator Marker, $j = 1, 2, \dots, m$				
		X_1	X_2	X_3	$\dots$	X_m
$i = 1, 2, \dots, n$	E_1	R_{a1}	R_{a2}	R_{a3}	$\dots$	R_{am}
	E_2	R_{b1}	R_{b2}	R_{b3}	$\dots$	R_{bm}
	E_3	R_{31}	R_{32}	R_{33}	$\dots$	R_{3m}
	$\dots$	$\dots$	$\dots$	$\dots$	$\dots$	$\dots$
	E_n	R_{n1}	R_{n2}	R_{n3}	$\dots$	R_{nm}

The average of the sum of the ranks is calculated as follows [50]:

$$\sum_{i=1}^n R_{ij} - \frac{1}{2}n(m+1), \quad (5)$$

where R_{ij} is a rank of R , m is the number of benchmarks, and n is the number of experts.

$$W = \frac{12S}{n^2m(m^2-1)} = \frac{12S}{n^2(m^3-m)}, \quad (6)$$

where W is the concordance coefficient, and S is the sum of the squares of the deviation from the arithmetic mean. The Pearson criterion χ^2 is calculated by the following formula:

$$\chi^2 = n(m-1)W = \frac{12S}{nm(m+1)}, \quad (7)$$

The minimum value of the concordance coefficient $W_{\min}$ is equal to

$$W_{\min} = \frac{\chi_{v,\alpha}^2}{n(m-1)}, \quad (8)$$

$$S_{\max} = \frac{n^2m(m^2-1)}{12}, \quad (9)$$

$$\bar{R} = \frac{1}{2}n(m+1). \quad (10)$$

If the variance S is a real sum of squares calculated according to Formula (5), then the concordance coefficient as calculated using Formula (6), in the absence of related ranks, is defined by the ratio of the resulting S to the corresponding maximum $S_{\max}$ in Formula (9). In the light of the experts' evaluation indicators (10), the consistency of their opinions is determined by calculating the concordance coefficient of the Kendall ranks. The lowest value of the concordance coefficient $W_{\min}$ is calculated using Formula (8). The threshold value for the concordance coefficient) where expert assessments can be considered coordinated) and the significance of the concordance coefficient can be determined by using the Pearson criterion χ^2 , as in Formula (7).

5. Research Results

The research was carried out in 2024, from September to October. Four experts (E1, E2, E3, and E4) with a university education and 10 continuous years of professional experience took part in the research (Table 4). The experts were selected from two large and two medium-sized companies. For the sake of objectivity and impartiality, two of the experts are warehouse managers who are strategic decision makers, i.e., they deal with issues related to warehouse automation. The other two are warehouse staff, working both in warehouses and at the university, who analyse logistics innovations and put technology into practice in warehouse operations.

Table 4. Expert data (developed by the authors).

Expert	Education	Professional Experience	Occupation
E1	Master's	15	Manager
E2	Master's	12	Manager
E3	Master's	10	Manager
E4	Master's	11	Manager

The recommended number of members in an expert group should be no less than three in order to guarantee a better distribution of opinions and no greater than ten for results to be objective and reliable [50]. The optimal number of experts in a group varies between 8 and 10 members, and at least 5 experts should be surveyed. The reliability of evaluation slightly increases as the number of experts increases; however, the greatest accuracy of estimates can be obtained with five to nine experts in a group [51].

Two large and two medium-sized companies were selected for the study. Large companies focus on automation and have semi-automated warehouses. They use an intelligent transport management system to optimize routes and reduce empty journeys, as well as deploying a safety system on their trucks, including emergency braking and monitoring of driver vigilance.

Medium-sized companies have non-automated warehouses and understand the need for automation. They strive to manage freight flows efficiently and reduce the likelihood of human error, while digital order tracking platforms increase customer satisfaction and provide real-time data on shipments.

Experts rated each problem under discussion on the basis of their perceived importance from a scale of 1 (very important) to 9 (not important). It is necessary to normalize the experts' significance estimates (Table 5) whilst applying the weighted sum method. In this particular instance, normalization was performed from the total sum of estimates, and to confirm results, normalization was performed on the basis of maximum and minimum estimates. This did not influence the final result.

Table 5. The importance of IT factors in conducting warehouse functions.

Experts	E1		E2		E3		E4	
Factors of IT Processes	Rank	Normalized Values	Rank	Normalized Values	Rank	Normalized Values	Rank	Normalized Values
Unloading (ISV1)	7	0.156	3	0.067	6	0.133	5	0.111
Data check-up (ISV2)	1	0.022	2	0.044	1	0.022	1	0.022
Selecting storage location (ISV3)	4	0.089	1	0.022	2	0.044	2	0.044
Short-term storage (ISV4)	6	0.133	4	0.089	4	0.089	3	0.067
Long-term storage (ISV5)	9	0.200	7	0.156	8	0.178	9	0.200
Consolidation (ISV6)	2	0.044	8	0.178	3	0.067	4	0.089
Picking according to client wishes (ISV7)	3	0.067	5	0.111	5	0.111	6	0.133
Packaging (ISV8)	8	0.178	9	0.200	9	0.200	8	0.178
Order loading (ISV9)	5	0.111	6	0.133	7	0.156	7	0.156

The receiving function includes the processes of loading and data check-up by means of information systems; the putting away function deals with selecting a storage location; the warehouse storage function involves short-term and long-term storage processes; order picking encompasses consolidation and picking according to client wishes; and the shipping function involves packaging and order loading. After completing an analysis of arithmetic (AV), geometric (GV), and weighted sum (SAW) results for evaluating IT processes, based on constant and variable weight coefficients, the estimates correspond to positions in the queue (Table 6).

Table 6. Final values of expert assessment results based on the methods.

IS Processes	K1	K2	AV(K1)	AV(K2)	Rank (AV)	GV(K1)	GV(K2)	Rank (GV)	SAW(K1)	SAW(K2)	Rank SAW
ISV1	0.111111111	0.117	0.014	0.013	6	0.013	0.584	6	0.054	0.052	6
ISV2		0.028	0.001	0.003	1	0.001	0.033	1	0.003	0.012	1
ISV3		0.050	0.003	0.006	2	0.002	0.100	2	0.010	0.022	2
ISV4		0.094	0.009	0.010	3.5	0.009	0.389	4	0.036	0.042	3.5
ISV5		0.183	0.034	0.020	8	0.033	1.505	8	0.134	0.081	8
ISV6		0.094	0.009	0.010	3.5	0.008	0.352	3	0.036	0.042	3.5
ISV7		0.106	0.011	0.012	5	0.011	0.486	5	0.045	0.047	5
ISV8		0.189	0.036	0.021	9	0.036	1.603	9	0.143	0.084	9
ISV9		0.139	0.019	0.015	7	0.019	0.860	7	0.077	0.062	7

Notes: unloading—ISV1, data check-up—ISV2, selecting storage location—ISV3, short term storage—ISV4, long-term storage—ISV5, consolidation—ISV6, picking according to client wishes—ISV7, packaging—ISV8, order loading—ISV9, K1—constant weight coefficient, K2—expert weight coefficient, AV(K1), AV(K2)—arithmetic mean with constant weight coefficient, GV(K1)—geometric mean with constant weight coefficient, GV(K2)—geometric mean with expert weight coefficient SAW(K1)—weighted sum with constant weight coefficient, SAW(K2)—weighted sum with expert weight coefficients.

To summarize the results obtained from an expert assessment, it is possible to conclude that data check-up is the most important process to be improved in the warehouse information system. Another important process to be improved is the selection of storage

space, which belongs to the second warehouse function. Experts identified the processes in which the most errors occur whilst performing operations without introducing automation. They were placed in the following order based on the most errors: cargo preparation for distribution (O3)—first place, cargo consolidation (O4)—second place, and storage of the received cargo (O2)—third place (Table 7).

Table 7. The importance of logistics operation in performing functions.

Operation	Arithmetic Mean	Sequence (AV)	Geometric Mean	Sequence (GV)	SAW Coefficient	Expert Assessment Sum	SAW	Sequence SAW
O1	5.5	6	5.47722558	6	0.26190476	22	5.7619	6
O2	3.25	3	2.78315768	3	0.1547619	13	2.0119	3
O3	1.5	1	1.41421356	1	0.07142857	6	0.42857	1
O4	2.5	2	2.27950706	2	0.11904762	10	1.19048	2
O5	3.75	4	3.30975092	4	0.17857143	15	2.67857	4
O6	4.5	5	4.42672768	5	0.21428571	18	3.85714	5

Notes: receiving of cargo (from a central warehouse, factory, or supplier)—O1, storage of received cargo—O2, cargo preparation for distribution—O3, cargo consolidation—O4, cargo preparation for shipping—O5, cargo distribution to consumers—O6.

Experts assessed the improvement of information systems and warehouse automation factors in general (Table 8).

Table 8. The importance of process automation factors in a company.

Processes	Process Automation Factors	Arithmetic Mean	Sequence (AV)	Geometric Mean	Sequence (GV)	SAW Coefficient	Expert Assessment Sum	SAW	Sequence SAW
IT Improvement	AV1	6	7	5.85601028	7	0.21428571	24	5.14286	7
	AV2	4	4	3.30975092	4	0.14285714	16	2.28571	4
Warehouse Automation	AV3	1.25	1	1.18920712	1	0.04464286	5	0.22321	1
	AV4	2.5	2	2.44948974	2	0.08928571	10	0.89286	2
	AV5	5.25	5	5.2331757	5	0.1875	21	3.9375	5
	AV6	3.5	3	3.2237098	3	0.125	14	1.75	3
	AV7	5.5	6	5.29150262	6	0.19642857	22	4.32143	6

Notes: data collection and sharing among different functional areas—AV1, easily completed tasks that are complex and cannot be performed by a human—AV2, automated equipment that is located in the areas that are dangerous to employees—AV3, reduced labour costs—AV4, more accurate operations—AV5, reduced operation hours—AV6, reduced labor shortages—AV7.

To summarize the results obtained from the expert assessment, it is possible to claim that greater importance is given to factors pertaining to warehouse automation processes in comparison to improving information systems. The conclusion to be drawn is that information systems are extremely flexible and fully adapted to warehouse processes and functions.

The consistency of expert assessment is an important factor impacting the results of multi-criteria assessment methods. Since multi-criteria evaluation methods often rely on expert opinion, it is essential that experts have the necessary competencies and knowledge in their field. In each assessment, the concordance was calculated, and it was assumed

that all expert opinions were in agreement, as the average of the concordance coefficient is equal to 0.3975.

Experts were asked to assess how automation impacts warehousing processes and the service quality provided. The following criteria were evaluated:

receiving of cargo (from a central warehouse, factory, or supplier)—O1;

storage of the received cargo—O2;

cargo preparation for distribution—O3;

cargo consolidation—O4;

cargo preparation for distribution—O5;

cargo distribution to consumers—O6.

Expert rank distribution is provided in Figure 4.

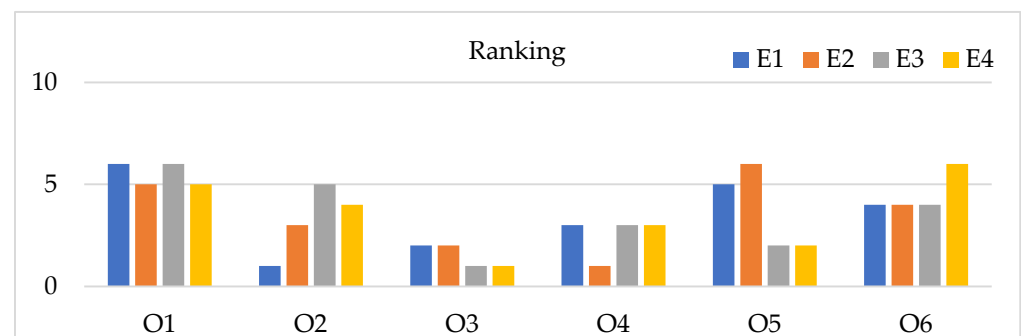


Figure 4. Rank distribution of expert assessment (developed by the authors).

The data of the calculation and analysis of the distribution of the rankings of four experts' criteria (in order of importance from 1 as the most important to 6 as the least important) are listed in Table 9.

Table 9. Data of the obtained ranks (developed by the authors).

Mathematical Expression of the Criterion	Criterion Encryption Symbol ($m = 6$)					
	O1	O2	O3	O4	O5	O6
$\sum_{i=1}^n R_{ij}$	22	13	6	10	15	18
$\bar{R}_j = \frac{\sum_{i=1}^n R_{ij}}{n}$	5.5	3.25	1.5	2.5	3.75	4.5
$\sum_{i=1}^n R_{ij} - \frac{1}{2}n(m+1)$	8	−1	−8	−4	1	4
$\left[\sum_{i=1}^n R_{ij} - \frac{1}{2}n(m+1) \right]^2$	64	1	64	16	1	16

The concordance coefficient is calculated according to Equation (11) when there are no associated ranks:

$$W = \frac{12S}{n^2(m^3 - m)} = \frac{12 \times 162}{4^2(6^3 - 6)} = 0.57857. \quad (11)$$

Automation is important for improving the storage process when the number $m > 6$. The concordance coefficient is then calculated according to Equation (12) to obtain a random variable:

$$\chi^2 = n(m-1)W = \frac{12S}{nm(m+1)} = \frac{12 \times 162}{4 \times 6(6+1)} = 11.5714. \quad (12)$$

The χ^2 calculated value of 11.5714 is larger than the critical (equals 11.0705) value; as a result, the opinions of the responding experts are perceived as consistent, and the average ranks indicate the overall opinion of the experts [52].

According to Equation (13), the lowest value of the concordance coefficient $W_{\min}$ is calculated:

$$W_{\min} = \frac{\chi^2_{v,\alpha}}{n(m-1)} = \frac{11.0705}{4(6-1)} = 0.55353 < 0.57857. \quad (13)$$

If $W_{\min} = 0.55353 < 0.57857$, then the opinions of all four respondents on the four criteria for automation are important for improving the storage process and are still considered to agree.

The indicators of the importance of the impact of automation are paramount for improving the storage processes and are calculated as follows: Q_j . The acquired data and all automation methods are significant in improving the storage process criteria and are presented from the most important to the least important in Table 10.

Table 10. Results of ranking (compiled by the authors).

Indicator Marker	Criterion Encryption Symbol ($m = 6$)						Sum
	O1	O2	O3	O4	O5	O6	
q_j	0.2619	0.1548	0.0714	0.1190	0.1786	0.2143	1
d_j	0.7381	0.8452	0.9286	0.8810	0.8214	0.7857	5
Q_j	0.1476	0.1690	0.1857	0.1762	0.1643	0.1571	1
Q_j'	0.0714	0.1786	0.2619	0.2143	0.1548	0.1190	1
Distribution of importance of criteria	6	3	1	2	4	5	—

Based on expert assessments and calculations, the criteria for automation are considered to be important in improving storage processes. The elements and the criteria under assessment are listed below.

- (1) preparation of cargo for distribution—O3;
- (2) cargo consolidation—O4;
- (3) storage of the received cargo—O2;
- (4) preparation of cargo for distribution—O5;
- (5) cargo distribution to consumers—O6;
- (6) receiving of cargo (from a central warehouse, factory, or supplier)—O1.

The impact of automation on the quality of warehousing processes is shown in Figure 5.

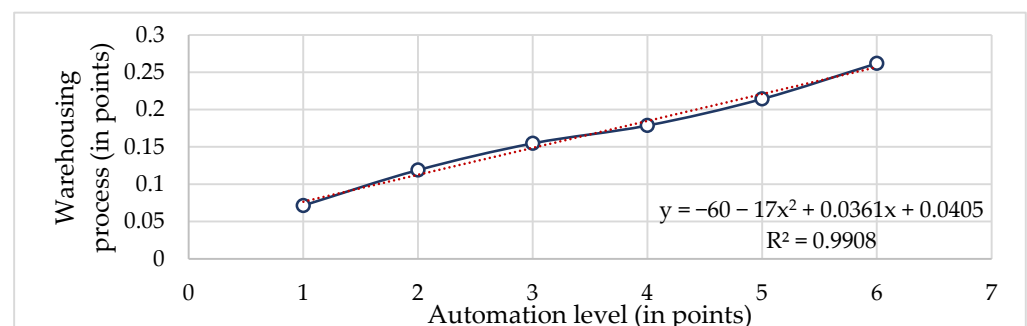


Figure 5. The impact of automation on the quality of warehousing processes (developed by the authors).

The estimates of the second-degree polynomial criteria (Figure 5) indicate that a 3-fold increase in the applications of automation systems enhanced the quality of warehousing processes by 2.5 times.

Experts were asked to assess when logistics systems should be implemented to improve service quality. The following criteria were evaluated:

data collection and sharing among different functional areas—AV1;

easily completed tasks that are complex and cannot be performed by a human—AV2; automated equipment located in the areas that are dangerous to employees—AV3; reduced labour costs—AV4; more accurate operations—AV5; reduced operation hours—AV6; reduced labor shortages—AV7.

The distribution of expert ranks is presented in Figure 6.

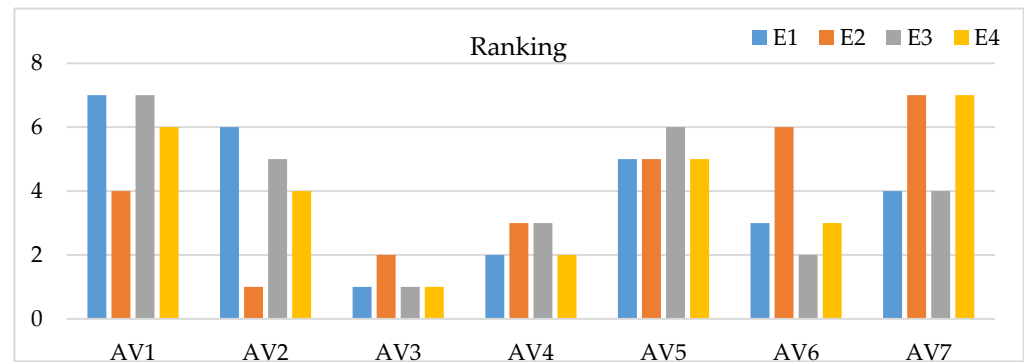


Figure 6. Ranking distribution whilst determining the need to implement logistics systems and improve service quality (developed by the authors).

The data of the analysis and calculation of the distribution of the rankings of four experts' criteria (in order of importance from 1 as the most important to 7 as the least important) are listed in Table 11.

Table 11. Data of the obtained ranks (developed by the authors).

Mathematical Expression of the Criterion	Criterion Encryption Symbol ($m = 7$)						
	AV1	AV2	AV3	AV4	AV5	AV6	AV7
$\sum_{i=1}^n R_{ij}$	24	16	5	10	21	14	22
$\bar{R}_j = \frac{\sum_{i=1}^n R_{ij}}{n}$	6	4	1.25	2.5	5.25	3.5	5.5
$\sum_{i=1}^n R_{ij} - \frac{1}{2}n(m+1)$	8	0	−11	−6	5	−2	6
$\left[\sum_{i=1}^n R_{ij} - \frac{1}{2}n(m+1) \right]^2$	64	0	121	36	25	4	36

The concordance coefficient calculated according to Equation (14) when no associated ranks are present:

$$W = \frac{12S}{n^2(m^3 - m)} = \frac{12 \times 286}{4^2(7^3 - 7)} = 0.63839. \quad (14)$$

The logistics systems criterion is important for service quality, where the number $m > 7$. The concordance coefficient is then calculated according to Equation (15) to obtain a random variable:

$$\chi^2 = n(m-1)W = \frac{12S}{nm(m+1)} = \frac{12 \times 286}{4 \times 7(7+1)} = 15.3214. \quad (15)$$

The calculated value of χ^2 is 15.3214, which is larger than the critical value (which equals 12.5916); consequently, the opinion of the experts is considered to be consistent, and the average ranks indicate the overall opinion of the experts [52].

According to Equation (16), the lowest value of the concordance coefficient $W_{\min}$ is calculated:

$$W_{\min} = \frac{\chi_{v,\alpha}^2}{n(m-1)} = \frac{12.5916}{4(7-1)} = 0.52465 < 0.63839. \quad (16)$$

If $W_{\min} = 0.52465 < 0.63839$, then the opinions of all four respondents on the seven criteria for logistics systems, with the aim of improving service quality, are considered to be in agreement. These criteria are important for logistics systems in which the aim is to improve service quality.

The indicator of the importance of the impact of logistics systems are implemented when the aim is to improve service quality, and it is calculated as follows: Q_j . The obtained data and all logistics systems are implemented when the aim is to improve service quality. The criteria and their order from most to least important are presented in Table 12.

Table 12. Results of ranking logistics systems that can be implemented when the aim is to improve service quality (compiled by the authors).

Indicator Marker	Criterion Encryption Symbol ($m = 7$)							Sum
	AV1	AV2	AV3	AV4	AV5	AV6	AV7	
q_j	0.2143	0.1429	0.0446	0.0893	0.1875	0.1250	0.1964	1
d_j	0.7857	0.8571	0.9554	0.9107	0.8125	0.8750	0.8036	6
Q_j	0.1310	0.1429	0.1592	0.1518	0.1354	0.1458	0.1339	1
Q_j'	0.0714	0.1429	0.2411	0.1964	0.0982	0.1607	0.0893	1
Distribution of importance of criteria	7	4	1	2	5	3	6	—

Based on expert assessments and calculations, the criteria for logistics systems are implemented when the aim is to improve the quality of service. The elements and criteria under assessment are listed below:

- (1) automated equipment that is located in the areas that are dangerous to employees—AV3;
- (2) reduced labour costs—AV4;
- (3) reduced operation hours—AV6;
- (4) easily completed tasks that are complex and cannot be performed by a human—AV2;
- (5) more accurate operations—AV5;
- (6) reduced labor shortages—AV7;
- (7) data collection and sharing among different functional areas—AV1.

The impact of logistics systems on service quality is presented in Figure 7.

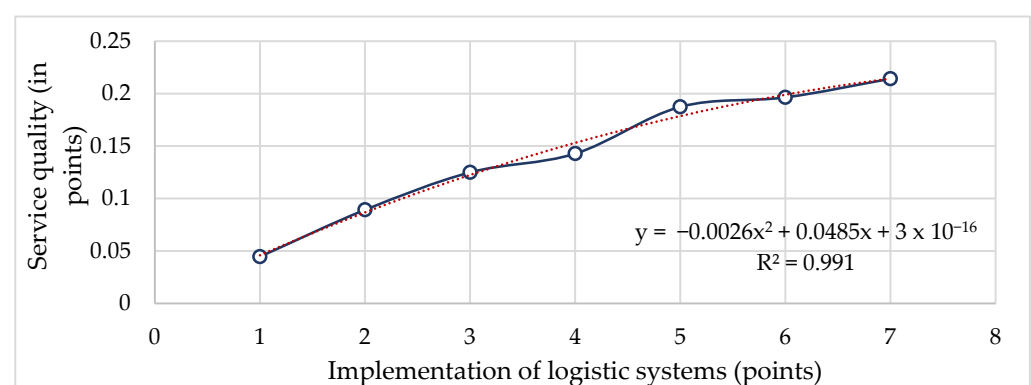


Figure 7. The impact of implemented logistics systems on the quality of warehousing services (developed by the authors).

The estimates of the second-degree polynomial criteria (Figure 7) indicate that a 3-fold increase in the applications of logistics systems enhanced the quality of warehousing services by 2.3 times.

Experts were asked to assess the problem areas within big data processing in which the functions of logistics systems should be improved. The following criteria were assessed:

unloading—ISV1;
 data check-up—ISV2;
 selecting storage location—ISV3;
 short term storage—ISV4;
 long-term storage—ISV5;
 consolidation—ISV6;
 picking according to client wishes—ISV7;
 packaging—ISV8;
 order loading—ISV9.

The distribution of expert rankings is presented in Table 5.

The data of the analysis and calculation of the distribution of the rankings of four experts' criteria (in order of importance from 1 as the most important to 7 as the least important) are listed in Table 13.

Table 13. Data of the obtained ranks (developed by the authors).

Mathematical Expression of the Criterion	Criterion Encryption Symbol ($m = 9$)								
	ISV1	ISV2	ISV3	ISV4	ISV5	ISV6	ISV7	ISV8	ISV9
$\sum_{i=1}^n R_{ij}$	21	5	9	17	33	17	19	34	25
$\bar{R}_j = \frac{\sum_{i=1}^n R_{ij}}{n}$	5.25	1.25	2.25	4.25	8.25	4.25	4.75	8.5	6.25
$\sum_{i=1}^n R_{ij} - \frac{1}{2}n(m+1)$	1	−15	−11	−3	13	−3	−1	14	5
$\left[\sum_{i=1}^n R_{ij} - \frac{1}{2}n(m+1) \right]^2$	1	225	121	9	169	9	1	196	25

The concordance coefficient, calculated according to Equation (17), when there are no associated ranks is

$$W = \frac{12S}{n^2(m^3 - m)} = \frac{12 \times 756}{42(9^3 - 9)} = 0.7875. \quad (17)$$

Problem areas in processing large amounts of data where the functionality of logistics systems should be improved are important within overall service quality, where $m > 9$. The concordance coefficient is then calculated according to Equation (18) to obtain a random variable:

$$\chi^2 = n(m-1)W = \frac{12S}{nm(m+1)} = \frac{12 \times 756}{4 \times 9(9+1)} = 25.20. \quad (18)$$

The calculated value of χ^2 is 25.20, which is larger than the critical value (15.5073); as a result, the opinion of the responding experts is considered to be consistent, and the average ranks indicate the overall opinion of the experts [52].

According to Equation (19), the lowest value of the concordance coefficient $W_{\min}$ is calculated:

$$W_{\min} = \frac{\chi_{v,\alpha}^2}{n(m-1)} = \frac{15.5073}{4(9-1)} = 0.4846 < 0.7875. \quad (19)$$

If $W_{\min} = 0.4846 < 0.7875$, then the opinions of all four respondents on the nine criteria of problem areas (including processing big flows of information) where the functionality of logistics systems should be improved are in agreement. These criteria are important for logistics systems when the aim is to improve service quality in distributing and processing big flows of information.

The indicators of the importance of the impact of problem areas in processing large amounts of data, where the functionality of logistics systems should be improved, are calculated as follows: Q_j . The criteria and their order from most to the least important are listed in Table 14.

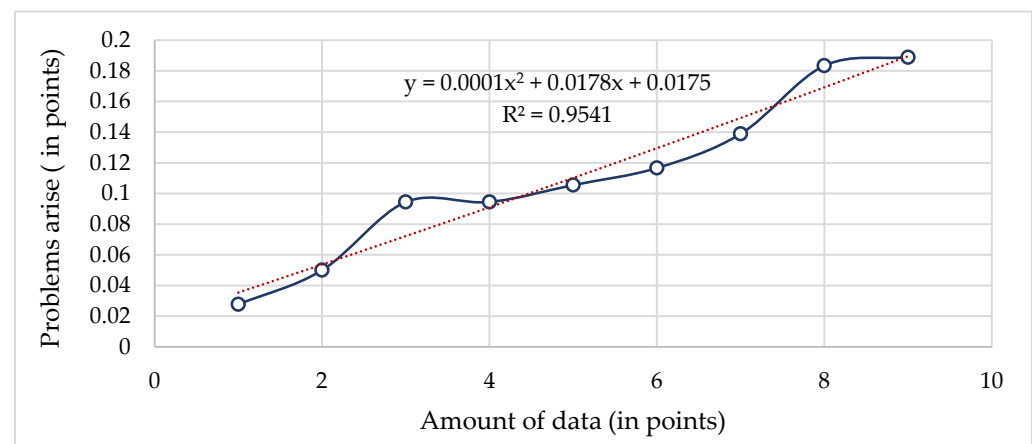
Table 14. Results of ranking problem areas in processing large amounts of data, where the functionality of logistics systems should be improved (compiled by the authors).

Indicator Marker	Criterion Encryption Symbol ($m = 9$)									Sum
	ISV1	ISV2	ISV3	ISV4	ISV5	ISV6	ISV7	ISV8	ISV9	
q_j	0.1167	0.0278	0.0500	0.0944	0.1833	0.09444	0.1056	0.1889	0.1389	1
d_j	0.8833	0.9722	0.9500	0.9056	0.8167	0.9056	0.8944	0.8111	0.8611	8
Q_j	0.1104	0.1215	0.1188	0.1132	0.1021	0.1132	0.1118	0.1014	0.1076	1
Q_j'	0.1056	0.1944	0.1722	0.1278	0.0389	0.1278	0.1167	0.0333	0.0833	1
Distribution of importance of criteria	6	1	2	3.5	8	3.5	5	9	7	—

According to expert assessments and calculations, the elements and criteria for problem areas in processing large amounts of data, where the functionality of logistics systems should be improved, are presented below:

- (1) data check-up—ISV2;
- (2) selecting storage location—ISV3;
- (3.5) short-term storage—ISV4;
- (3.5) consolidation—ISV6;
- (5) picking according to client wishes—ISV7;
- (6) unloading—ISV1;
- (7) order loading—SV9;
- (8) long-term storage—ISV5;
- (9) packaging—ISV8.

The impact of big data on reducing bottlenecks in the logistics system is presented in Figure 8.

**Figure 8.** The impact of big data processing on the efficiency of logistics system management (developed by the authors).

The estimates of the second-degree polynomial criteria (Figure 8) indicate that a threefold increase in the data enhanced the probability of bottlenecks in the logistics system by five times, which negatively affects the quality of the service provided.

The use of automated warehouse solutions increases companies' competitive advantage and revenue, minimizes costs and the need for manual labor, eliminates the probability of human error, enhances working pace and efficiency, and effectively utilizes warehouse space. Automated warehouses improve the quality of services and speed up big data processing. To achieve a greater competitive advantage, fewer errors, and higher profits, companies must strive to automate warehouse processes using innovative technologies

such as warehouse management systems (WMSs), automated storage and retrieval systems (AS/RSs), automated guided vehicles (AGVs), and autonomous mobile robots (AMRs).

The Internet of Things (IoT) is necessary to connect and exchange data with other devices and systems over the Internet. Objects required for IoT integration and information exchange are embedded into systems with sensors, software, and other technologies. The Internet of Things enables real-time monitoring and actioning of devices. It also enables the collection and processing of large amounts of data without human intervention. Therefore, the diagram of warehouse automation possibilities in Figure 2 is supplemented by the Internet of Things. Warehouse automation can be accomplished by using the Internet of Things, automated warehouse vehicles, autonomous mobile robots, and an automated storage and retrieval system (Figure 9).

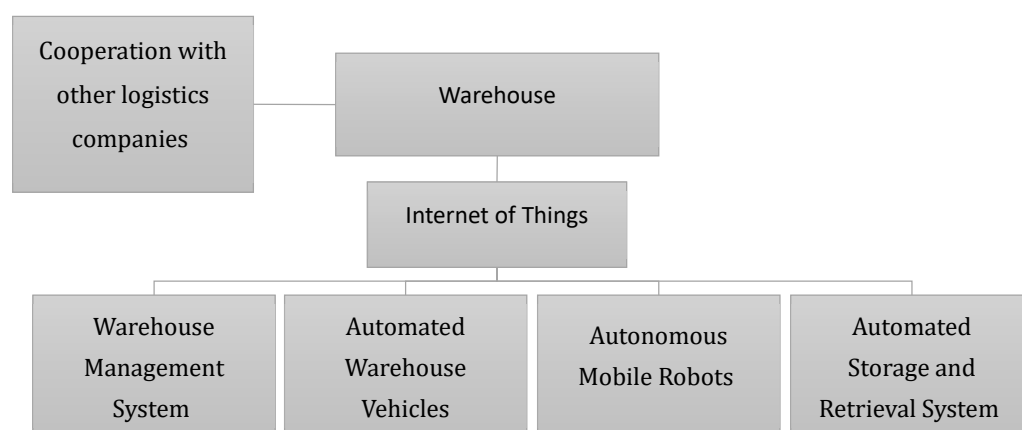


Figure 9. Newly defined factors of warehouse automation opportunities.

Such an addition will help to make reliable and quick decisions during operations performed in warehousing processes, which will improve the speed and quality of service provision (Figure 9). Automation in warehousing processes must allow real-time monitoring of the number of products, where those products are moving, and with which vehicle they are moving. This becomes very important in the context of collaborative warehousing services, where an amount of data is received and processed by innovative systems. Warehouse automation is becoming an integral part of collaboration, as it helps information be presented, exchanged, and processed, thereby improving the quality of the service provided.

6. Discussion

The process of warehouse automation results in more accurate and precise operations than those performed by human employees [18]. It is also possible to reduce the manual labour required [19]. Research results have shown that automation processes are extremely important in warehouse operations. Moreover, research results have confirmed that warehouse automation is imperative in certain operations where involvement of human employees might be dangerous; thus, the need for a human labour force is significantly reduced; i.e., to speed up the work, it is necessary to purchase automated vehicles and autonomous mobile robots.

Michelet et al. [19] and Alum & Kesen [23] claim that human errors occur in the majority of warehousing processes. Experts have identified the processes in which the most errors occur in operations without the introduction of automation, i.e., the preparation of cargo for distribution. Kumar et al. (2022) emphasize that there is currently an increased need for research into IoT technologies in warehousing processes [53]. The researcher notes that survey-based research has increased in developed countries. It is also noted

that the implementation of the Internet of Things and automation in companies are being driven by the legal regulation of business and consumers of logistics company services interested in sustainability. Lydia et al. (2022) presented a warehouse that operates under the control of the Internet of Things, with sensors in its storage system that regulate the microclimate of the warehouse environment. Temperature, humidity, and smoke sensors transmit information to a controller that turns on a humidifier, water sprinklers, or other devices [54].

Outdated systems are responsible for improper cargo storage [14]. As companies' priorities change, improving information systems is a continuous process; therefore, whilst applying new warehouse automation tools, timely corrections of logistics information systems are necessary, and the information systems used should be extremely flexible and adapted to warehouse processes and functions.

To provide a high-quality logistics service and gain a competitive advantage, Pečenyta et al. [55] emphasize the coordination of large flows of information and their important role in optimizing the supply chain. Information technologies, including automation systems, play an important role and ensure that warehousing services are performed to a high standard in all logistics processes. Boute and Udenio [56] emphasize that when switching to AI in logistics, all business elements can be managed precisely with the help of AI. AI's ability to perform higher-quality and faster logistics operations can improve the overall efficiency of logistics companies.

The success of automation factors significantly depends on the trust established among employees and the reputation of the AI being used. Ribeiro et al. [57] highlighted the trust between the user and the prognosis of the AI model. If the user does not trust the AI, he will be reluctant to use it in the future. As might be expected, integrating AI into logistics business processes allows a company to reduce the number of human errors that occur, increase the speed of information transfer in operations, and increase the company's operating income [58].

Abdullah et al. [59] indicated that automation contributes to the greater efficiency of company operations, the greater quality of decisions made, and the acceleration of search operations.

7. Limitations

The question of the reliability of the results emerges, as transport and logistics companies of different sizes were not surveyed in this research. The interviewed experts represented major Lithuanian carriers only. The levels of warehouse automation, the management systems used, and the volumes of logistics depend on the size of the company. Therefore, the opinions of the experts collected are quite subjective. The implementation of warehouse automation measures requires substantial financial resources from the company; thus, it is an important factor in the decision-making process.

8. Conclusions

Market changes, growing competition, and manual labour create a great many inconsistencies in warehousing processes. Excessive cargo handling, outdated equipment, shortage of mechanized processes, incorrect placement of cargo, and the slow pace of operations all contribute to the reduced quality of warehousing process. Thus, companies that own warehouses and wish to remain in the market, enhance their competitive advantage, and organize data sharing in a sustainable manner must integrate automated technologies into their everyday practices. Such technologies might include but are not limited to diverse warehouse management systems, automated storage and retrieval systems, automated vehicles, and autonomous mobile robots.

It has been determined that real-time monitoring of equipment is possible with the help of the Internet of Things, which improves the warehousing process and affects warehousing automation. On this basis, the warehousing automation model (Figure 2) is adjusted by adding the Internet of Things (Figure 9)

It is necessary to assess the current situation and make timely adjustments to warehouse automation and information systems whilst optimizing and making warehouse processes more efficient. Identifying problem areas in warehouse automation requires assessment and problem resolution. Expert assessment perfectly serves this purpose by providing consistent results; this method is time-efficient, simple, and easy to integrate. The requirements of this kind of study are best met using arithmetic, geometric, weighted sum, and expert ranking methods.

The majority of errors occur in the following warehouse operations: receiving of cargo (from a central warehouse, factory, or supplier); storage of the received cargo; preparation of cargo for distribution; cargo consolidation; and preparation of cargo for consumers. Experts have also identified the processes wherein most errors occur in operations without introducing automation, as follows: preparation of cargo for distribution, cargo consolidation, and storage of received cargo. It was determined that data check-up and selecting storage locations are some of the most important factors in carrying out warehouse functions.

The results of expert assessment show that automation processes are paramount in warehouse operations, particularly in those areas where human involvement might be dangerous; thus, to increase operational safety and the overall pace of operations, it is crucial for companies to purchase automated vehicles and autonomous mobile robots. As companies' priorities change, improving information systems is a continuous process; therefore, whilst applying new warehouse automation measures, timely corrections made to logistics information systems are necessary.

The present research can be extended beyond multi-criteria evaluation methods. Similar studies can be conducted in other types of areas, including transportation warehousing, non-standard modeling (e.g., for pandemics), unstable geopolitics, and movement-restricting situations.

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