SILESIAN UNIVERSITY OF TECHNOLOGY PUBLISHING HOUSE

SCIENTIFIC PAPERS OF SILESIAN UNIVERSITY OF TECHNOLOGY 2025
ORGANIZATION AND MANAGEMENT SERIES NO. 237

THE IMPACT OF RFID TECHNOLOGY ON WEARHOUSE AND INVENTORY MANAGEMENT IN A MANUFACTURING COMPANY

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Purpose: The aim of the article is to analyze the impact of RFID technology on warehouse and inventory management on the example of a selected manufacturing company. The research problem took the form of a question: What role does the implementation of RFID technology play in warehouse management?
Design/methodology/approach: The study is based on a case study of the analyzed company, in which a diagnosis of warehouse problems was carried out using tools such as SWOT analysis and Ishikawa diagrams. Then, an RFID implementation model was proposed, taking into account technical infrastructure, system integration (WMS, ERP), staff training and data analysis. The approach combines qualitative analysis and technological solution design in a logistics context.
Findings: The implementation of RFID allowed for the automation of warehouse processes, improved inventory accuracy, reduced number of errors and better management of warehouse space. Goods identification was improved, order fulfillment time was shortened and operational transparency was increased. Potential implementation limitations were also identified and discussed in detail.
Research limitations/implications: The study was conducted on the example of one enterprise, which may limit the possibility of full generalization of the results. Technological, financial and organizational barriers related to the implementation of RFID were also pointed out. Future research is suggested to be extended to other industries and to analyze the impact of RFID in the broader supply chain context.
Practical implications: The research results have direct application in warehouse management practice. The use of RFID can contribute to increasing operational efficiency, reducing logistics costs, improving the quality of customer service and reducing human errors. The proposed model can be used by other companies as a model for implementing the technology.
Social implications: Implementing RFID can improve working conditions by reducing errors and increasing automation. It indirectly affects the quality of services for end customers and can also support the development of modern, sustainable supply chains, having a positive impact on the environment and social responsibility of companies.
Originality/value: The paper adds value by presenting a comprehensive RFID implementation model in the operational context of a manufacturing enterprise. A unique element is the combination of the analysis of logistic problems with the proposal of a practical technological

solution. The recipients are logistics managers, warehouse management practitioners and RFID technology researchers.
Keywords: RFID, warehouse management, process.
Category of the paper: Research paper.

1. Introduction

RFID (Radio Frequency Identification) technology is playing an increasingly important role in modern warehouse and inventory management, introducing significant improvements to everyday logistics operations (Attaran, 2020; Sarac et al., 2010). Manufacturing companies that operate in a dynamic business environment are constantly looking for solutions that will allow them to increase the efficiency, precision and security of resource management (Bottani, Rizzi, 2008; Chowaniec, Pamuła, 2018). In this context, RFID, as a technology enabling wireless identification of objects and remote reading of information, offers a new quality in warehouse management (Ngai et al., 2012; Dlodlo, Mafini, 2013).

One of the key advantages of RFID is the automation of processes, which significantly reduces the time needed for inventory control, inventory and tracking the flow of goods (Lee, Özer, 2007; Gaukler et al., 2007). The ability to read data without the need for manual scanning allows for faster and more precise inventory management, which in turn minimizes human errors, reduces operational costs and increases the smoothness of logistics activities (Jones et al., 2005; Szozda, 2012). In addition, RFID provides greater control over the security of goods, so that companies can better protect their assets against theft or unauthorized access (Tajima, 2007; Garfinkel, Rosenberg, 2005).

Modern manufacturing companies that operate in increasingly complex and global supply chains must constantly adapt their logistics strategies to changing market conditions and growing customer expectations (Harisson, Van Hoek, 2008; Turoń, 2021). The implementation of RFID technology is the answer to these challenges, enabling enterprises to better integrate warehouse processes with the entire supply chain and providing access to accurate data in real time (Montanari, Rinaldi, 2004; Pruska, 2015). For this reason, RFID is becoming one of the key tools used by companies that strive to improve their efficiency and competitiveness on the market (Kłos, Patalas-Maliszewska, 2014; Liu, Liu, 2011).

2. Literature review

The process of implementing RFID technology in a company is a multi-stage undertaking that requires appropriate preparation and coordination (Gubi, Strom, 2005; Krzyżanowski, 2019). The first step is to thoroughly understand the company's needs and define the goals of RFID implementation. This includes analyzing areas where RFID technology can bring the greatest benefits, such as warehousing, production, transportation and sales support (Chappell, 2004; Karppinen, 2010). At this stage, specific problems that RFID can solve are also identified, e.g. improving inventory management or accelerating the order picking process (Witkowski, 2010; Pujawan, Geraldin, 2009). RFID comes in various forms, such as passive, semi-passive and active tags, which differ in range, data capacity and cost (Bhuptani, Moradpour, 2005; Rogers, Tibben-Lembke, 2006).

The next step is to prepare the infrastructure needed to implement RFID. This includes installing RFID readers in key locations, such as entry and exit points to warehouses, production stations, and transportation lines (Gunther, Kletti, 2007; Łaguna, 2017). You also need to provide appropriate software for integration with existing company management systems (ERP, WMS). Before fully implementing RFID technology, it is important to test it on a smaller scale, e.g. on a selected production line or in one warehouse (Haberman, 2004; Waller, Fawcett, 2013). Piloting allows you to assess the operation of the system, identify potential problems and collect information needed to optimize the entire process (Szozda, 2012; Ngai et al., 2012).

The success of RFID implementation largely depends on the preparation of staff. Employees responsible for operating the RFID system, both in production and warehousing, must undergo appropriate training to understand how the system works, how to read data from tags, and how to use the information in everyday operations (Attaran, 2020; Dlodlo, Mafini, 2013). After successful completion of the pilot phase, the company can proceed to full implementation of RFID on all production lines, warehouses and distribution points. It is important at this stage to monitor system performance and respond to possible problems (Liu, Liu, 2011; Pujawan, Geraldin, 2009).

Once fully implemented, it is crucial to continuously monitor the performance of the RFID system. The effectiveness, costs and benefits of technology should be analyzed and processes should be continuously optimized (Turoń, 2021; Waller, Fawcett, 2013). This may include infrastructure improvements, software updates or employee training. RFID can be combined with other technologies such as GPS, IoT or data analysis systems to increase the efficiency of the entire supply chain (Witkowski, 2010; Sarac et al., 2010). This integration allows for even better product tracking and optimization of operations.

The implementation of RFID technology is a long-term process that requires careful planning and coordination, but in return offers many benefits, such as greater supply chain transparency, better inventory control, and optimization of logistics processes (Ngai et al., 2012; Harrisson, Van Hoek, 2008).

3. Research Methodology

The structure of key processes in Enterprise includes five blocks of operations. The first is obtaining orders from customers, which includes not only distribution and production orders, but also those related to projects. After receiving the order, you proceed to the stage of purchasing individual elements necessary to meet the customer's requirements. The nature of your purchases may vary significantly depending on the type of order. Then, once the purchasing process is complete, the actions vary depending on the type of order. In the case of design orders, the project preparation phase begins, while for distribution and production orders, the production phase begins, closely related to the process of cooperation between many organizational units of the company. After completing production or project preparation, the sales phase began. It is worth noting that at each point of implementation of the company's main processes, complaint actions may occur related to a given stage of order fulfillment. Figure 1 shows a simplified diagram of the main processes in the analyzed company.

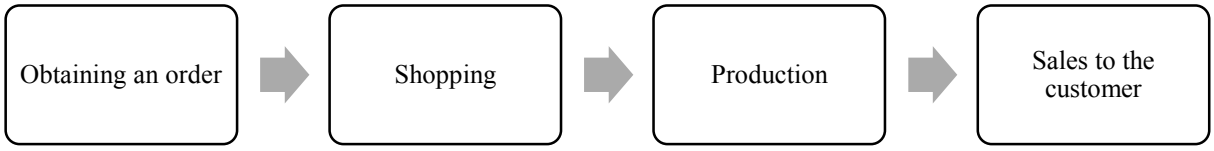

Figure 1. Main processes taking place in the analyzed company.

Source: Own study based on data from the surveyed company.

As part of the activities of company, the storage aspect is partially taken into account in processes such as purchasing, cooperation, production and sales. In the cooperation-production process in the analyzed company, storage is an activity that precedes the actual production of electronic modules. This is dictated by the frequent request of customers who require the use of their own components when carrying out production orders. Therefore, before production begins, the design department and the purchasing department must coordinate the introduction of a new product into the system and purchase the necessary materials. After the customer delivers the materials, warehouse employees accept the delivery, which allows the production process to begin. According to the discussed logistics process, the warehouses of Enterprise participate in three main processes: purchases, cooperation-production and sales. Furthermore, storage plays an important role in numerous more detailed procedures. The product sales process in the context of warehousing consists of three stages and is closely related to the activities of the sales department. This process involves the following activities:

- issuing sales documents by the sales department,
- issuing goods through the warehouse,
- sending goods to the final recipient.

In addition to the warehouse, the purchasing department and logistics department also participate in the process of purchasing elements for production. As part of this process, the tasks performed can be divided into the following three stages:

- placing an order for goods by the purchasing department,
- coordination of transport by the logistics department,
- receipt of goods by the warehouse.

In order to identify problems in warehousing logistics, a SWOT analysis was carried out, which can be used to observe the conditions for a new entity to enter the market and to identify areas requiring improvement. This is one of the most popular methods of strategic analysis, which can also be used in advisory activities - consulting as a form of organizational diagnosis. It can also be used in various areas of a company's operation - marketing, finance, production and sales. The name of the method is an acronym of the English words strengths, weaknesses, opportunites (potential or existing opportunities in the environment), threats (probable or existing threats in the environment) (Machaczka, 2001). All of the above-mentioned elements should be classified due to the fact that each of them is important in the final assessment of the company's situation. They can be classified as external to the organization and internal, which have a negative or positive impact on the organization. internal conditions and having a negative or positive impact on the organization. For this purpose, a scheme is used that divides the SWOT analysis factors into four categories:

- external positives (chances or opportunities) - these are factors that enable maintaining or increasing the market position,
- negative external (threats) - this is the identification of elements that have a negative impact on the development of the enterprise,
- internal positives (strengths) - identification of these elements is possible thanks to knowledge of the subject of the analysis, the more accurate it is, the more effective and reliable the result is,
- internal negatives (weaknesses) - their occurrence is most often caused by the lack of financial, human and other resources that block the company's development.

As a result of the analysis, strengths that need to be strengthened, weaknesses that need to be reduced, opportunities to be exploited and threats to be avoided can be identified. Table 1 contains the SWOT analysis for the examined the analyzed company.

Table 1.
SWOT analysis of the warehouse operation in the analyzed company

STRENGTHS	WEAKNESSES
• systematic adaptation of the warehouse layout to the evolving turnover structure, • planning deliveries in a way that eliminates time conflicts.	• unsatisfactory inventory management, • errors in the area of identification and labeling of goods, • suboptimal organization of warehouse space, • inappropriate use of technology, • problems with handling complaints, • lack of training for staff, • lack of process performance monitoring, • low level of warehouse automation, • small number of forklifts, • lack of feedback from suppliers, • problems with product availability.
OPPORTUNITIES	**THREATS**
• growing availability of technology, including software and hardware, enabling more effective warehouse management, • increasing market share of warehouse networks.	• changes in the supply system, • warehouse resources lying on the shelves, • the aging process of both buildings and technologies, • evolution of market needs, • constant employee turnover and the related need to invest in training for new employees.

Source: Own study based on data from the surveyed company.

Problems in the area of warehouse receipt, storage process and exit are illustrated in Ishikawa diagrams (Figures 2, 3, 4).

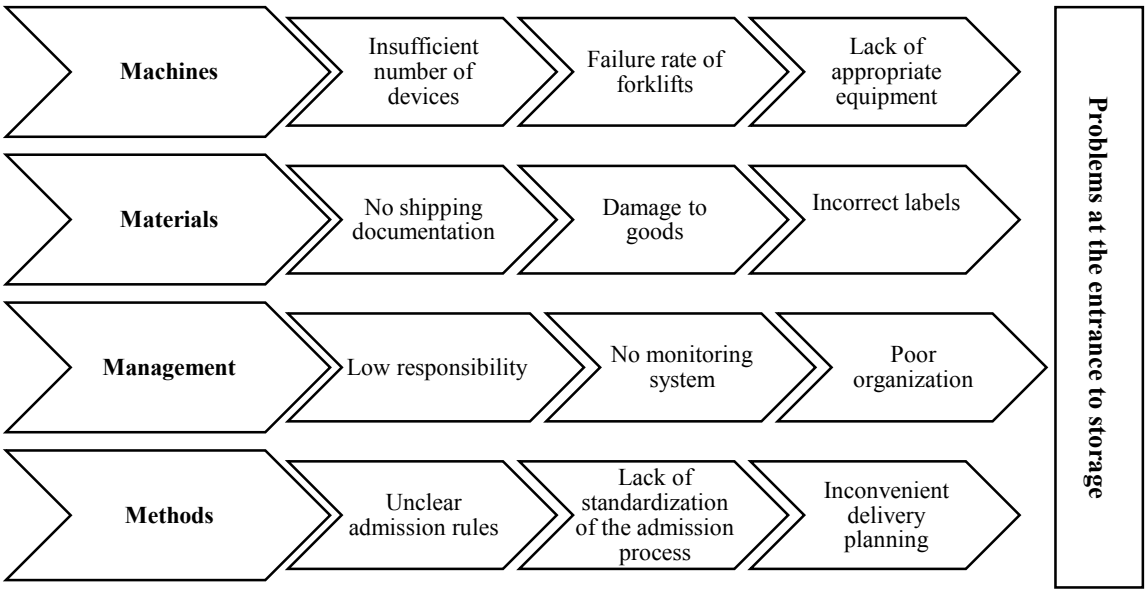

Figure 2. Ishikawa diagram in the area of goods receipt into the warehouse.

Source: Own study based on data from the surveyed company.

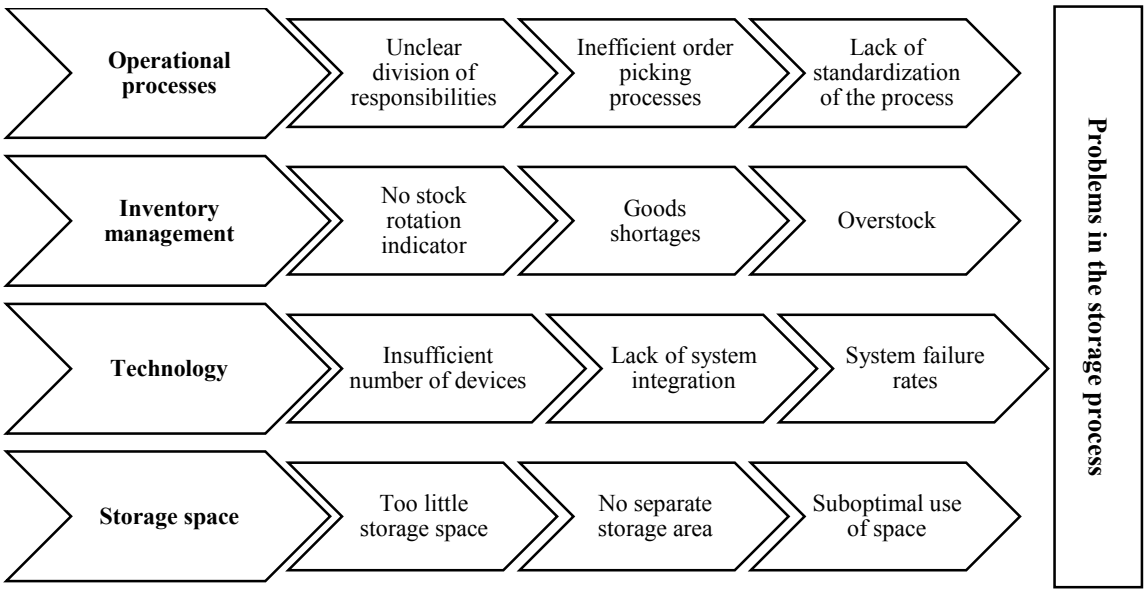

Figure 3. Ishikawa diagram in the area of the storage process.

Source: Own study based on data from the surveyed company.

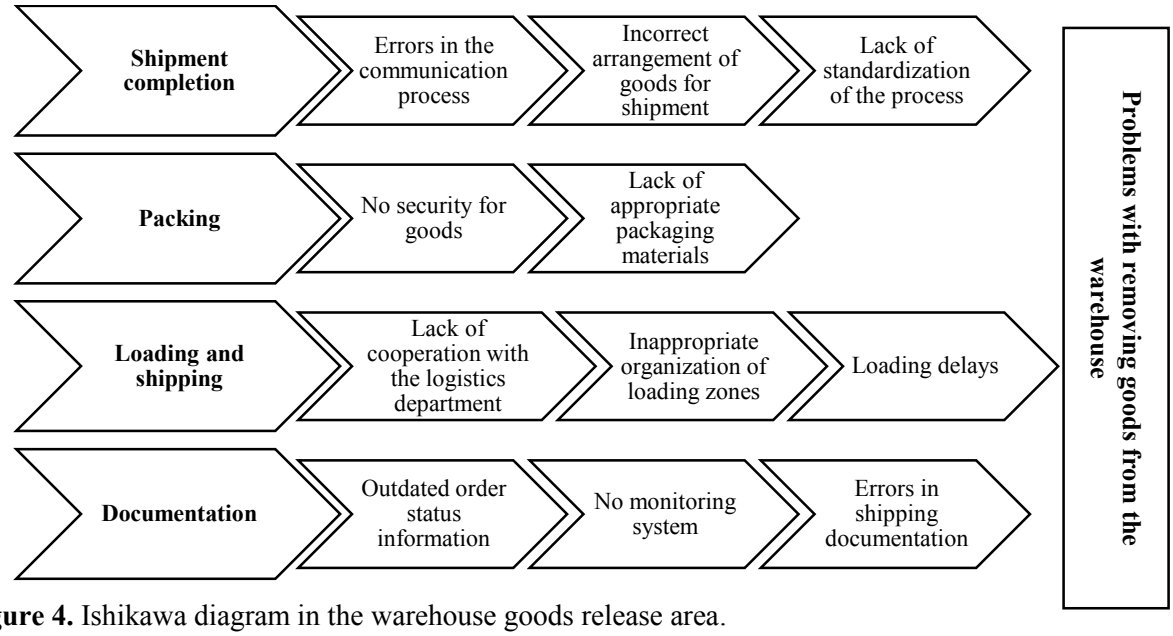

Figure 4. Ishikawa diagram in the warehouse goods release area.

Source: Own study based on data from the surveyed company.

Problems were identified in the area of warehouse receipt, storage process and output, which was presented in the above Ishikawa diagrams (Figures 4, 5, 6). To summarize these processes, a SWOT analysis was carried out (Table 2), which better illustrates the strengths, weaknesses, opportunities and threats related to these diagrams. In order to identify in detail the key conditions influencing the efficiency of warehouse processes in the analysis company, an in-depth SWOT analysis was conducted. This analysis allows for the assessment of both the internal resources and limitations of the organization, as well as external opportunities and threats that affect the way warehouse logistics functions. Compared to the classic approach, this version of SWOT has been expanded to include organizational, technological and strategic aspects, taking into account the specifics of implementing RFID technology.

Table 2.
SWOT analysis for the processes of receiving goods, storing and issuing goods in the analyzed enterprise

STRENGTHS	WEAKNESSES
• standardization of goods receipt processes, • organized storage areas in the warehouse, • effective order picking processes, • advanced inventory management systems, • clear loading and shipping procedures.	• lack of training in the identification of goods at reception, • ineffective organization of warehouse space, • delays in loading and shipping processes, • failure rate of warehouse equipment, • errors in shipment documentation
OPPORTUNITIES	**THREATS**
• automation of goods identification at reception, • expansion of warehouse space and better zone management, • integration of WMS technology with shipping processes, • implementation of new technologies for inventory management, • better training of warehouse staff.	• increasing requirements regarding the speed of receipt of goods, • increased risk of expired inventory in the warehouse, • problems with logistic synchronization in shipping processes, • growing competition in storage efficiency, • increased technology and infrastructure costs.

Source: Own study based on data from the surveyed company.

SWOT analysis of warehouse processes in the analyzed enterprise revealed both strengths that are worth developing, as well as significant weaknesses and threats that require urgent corrective actions. The main problems identified in the reception, storage and exit processes include: lack of staff training, ineffective organization of storage space, equipment failure rates and documentation errors. Additionally, threats such as growing customer requirements, increased competition and problems with logistic synchronization require the implementation of modern technological solutions. The response to the identified weaknesses and threats is the implementation of RFID technology, which will allow the analyzed company to significantly improve efficiency and eliminate key operational problems. RFID offers the possibility of automating the processes of identifying and monitoring goods, which will positively affect the speed, precision and inventory control throughout the entire warehouse cycle.

4. Results and Discussions

The implementation of RFID technology in the analyzed enterprise requires the development of a comprehensive model that will take into account all stages of the process, resources and benefits resulting from the implementation of this solution (Figure 5, 6, 7).

I MODEL INPUT DATA

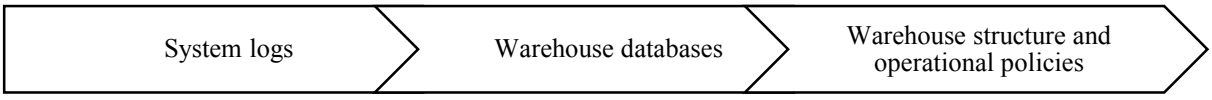

Figure 5. Model input data.

Source: Own study based on data from the surveyed company.

1. System logs:
   - Collecting information about activities in warehouse processes, such as registration of goods at the entrance, movement of goods between zones, goods leaving the warehouse.
   - These logs allow you to analyze process efficiency and identify errors in real time.
2. Warehouse databases:
   - Data on warehouse levels and goods rotation, excess and shortage of stocks, history of goods movements in the warehouse.
   - It allows you to optimize the use of space and prevent products from expiring.
3. Warehouse structure and operational policies:
   - Information on the location of reception, storage and exit areas, reception and loading policies.
   - Enables adaptation of RFID technology to existing infrastructure.
4. User interaction:
   - Intuitive interface enabling viewing data on warehouse stock, goods movements and generating reports.
   - Warehouse employees can monitor operations in real time and use recommendations generated based on RFID data.

II PROCESSES OF IMPLEMENTING RFID TECHNOLOGY

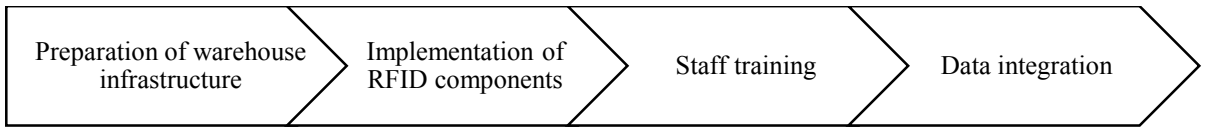

Figure 6. RFID technology implementation processes.

Source: Own study based on data from the surveyed company.

1. Preparation of warehouse infrastructure:
   - Installation of RFID antennas in receiving, storage and exit areas.
   - Implementation of RFID gates to record the flow of goods between zones.
   - Integration of RFID readers with the existing WMS system.
2. Implementation of RFID components:
   - RFID tags - placing tags on goods during reception, ensuring tags that are highly durable and adapted to the type of goods.
   - RFID readers - installation in key points of the warehouse, ensuring real-time data reading.
3. Staff training:
   - Training in the operation of RFID readers and the use of software.
   - Education on the interpretation of data generated by the RFID system.

4. Data integration:
   - Combination of RFID technology with WMS and ERP systems to automatically update inventory levels, generate reports on goods movement and inventory rotation.

III OUTPUT DATA

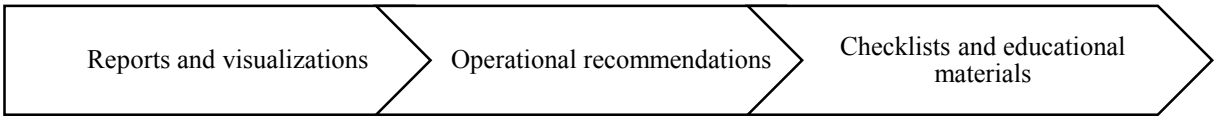

Figure 7. Model output data.

Source: Own study based on data from the surveyed company.

1. Reports and visualizations:
   - PDF reports with detailed data on goods flows, inventory rotation and errors in operations, creating comprehensive analyzes of warehouse efficiency.
   - Visualizations, diagrams of goods movement in the warehouse, statistics of errors, delays and product rotation.
2. Operational recommendations:
   - Proposals for actions aimed at reducing excess inventory, optimizing the distribution of goods, increasing the efficiency of loading and picking.
3. Checklists and educational materials:
   - Checklists, assessment of compliance of activities with warehouse policies.
   - Infographics, presenting key information about the operational efficiency of the warehouse and ways to avoid errors.

The implementation of RFID technology in the analyzed enterprise will improve the operational efficiency of the warehouse and increase the quality of logistics processes. Automation of warehouse processes will eliminate the need to manually enter data, because information about the flow of goods will be recorded automatically and updated in real time. RFID systems precisely monitor inventory levels and the movement of goods, which will increase the accuracy of operations and reduce the occurrence of errors. Figure 8 shows a comparison of key operational indicators before and after the implementation of RFID technology. There is a significant improvement in the time of delivery and order completion, as well as a reduction in warehouse errors by over 80%.

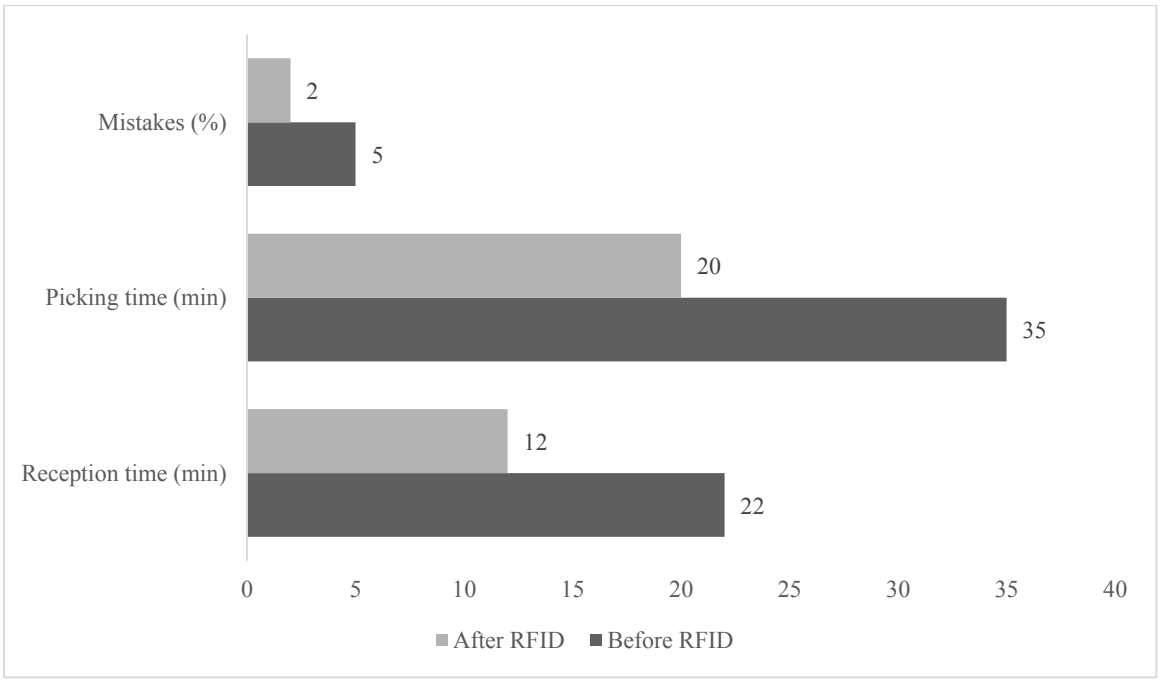

Figure 8. Comparison of key operational efficiency indicators of the warehouse before and after RFID implementation.

Source: Own study based on data from the surveyed company.

Moreover, RFID technology will significantly reduce the number of errors in warehouse processes. Precise tracking of goods at every stage, from receipt to loading, will help avoid errors in order picking and eliminate discrepancies in shipping documentation. Logistics processes will become more predictable and reliable, which will increase customer trust and satisfaction. Figure 9 illustrates the reduction in the number of documentation errors and complaints after RFID implementation. The reduction of errors from 73 to 9 cases and the decrease in complaints by 70% prove the greater precision of logistics processes.

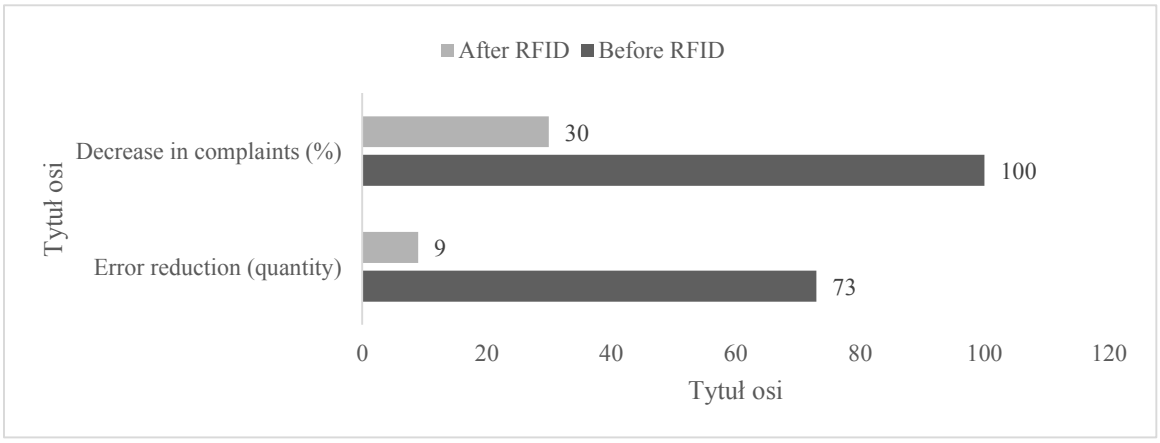

Figure 9. Reduction of documentation errors and complaints.

Source: Own study based on data from the surveyed company.

The ability to monitor the location and rotation of inventory will allow you to effectively use warehouse space, which will solve problems related to excess or shortage of goods. Figure 10 shows the level of warehouse losses before and after RFID implementation. The decrease from 2.4% to 0.5% indicates improved inventory control and reduced errors in merchandise records.

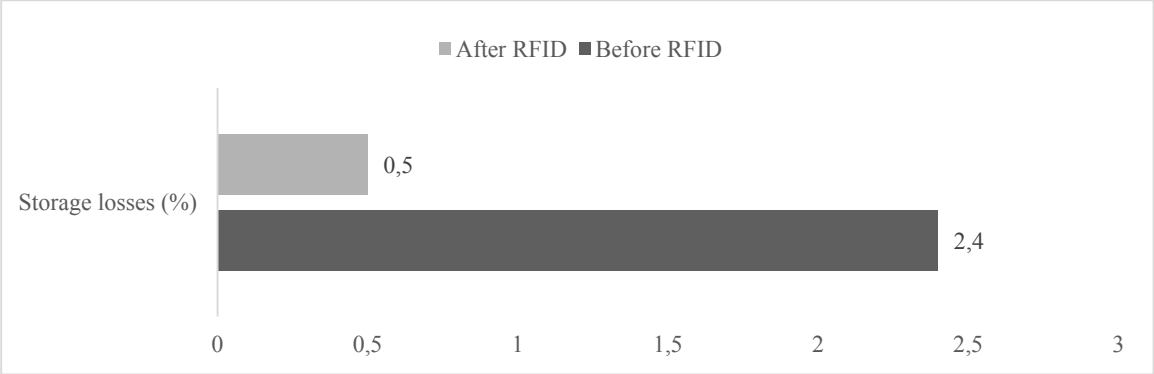

Figure 10. Decrease in the level of warehouse losses after the implementation of RFID technology. Source: Own study based on data from the surveyed company.

RFID will also improve the organization of warehouse operations, introducing greater transparency and control over key processes. This solution will increase the company's ability to quickly adapt to changing market conditions and customer requirements. RFID systems will provide flexibility and expandability, which will support the development of the company in the long term. Higher quality of inventory management and timely execution of orders will contribute to improving the company's competitiveness and strengthen its position on the market.

The implementation of RFID technology in the analyzed enterprise may encounter certain barriers and limitations that will need to be taken into account in the implementation process. One of the main challenges is the high initial cost associated with purchasing equipment such as RFID tags, readers and the IT infrastructure necessary to operate the system. For many enterprises, such an investment may constitute a significant financial burden, especially if the technology will be implemented on a large scale. Another barrier may be the lack of appropriate knowledge and experience in RFID technology among employees. The implementation process requires training so that staff can use the new tools effectively. Lack of appropriate

Some industries may encounter difficulties related to the physical limitations of RFID, such as interference in reading tags in the case of metal goods or goods stored in specific conditions, e.g. in cold stores. These technical limitations may impact the effectiveness of the system and require equipment to be adapted to the specific needs of the enterprise.

Managing data generated by RFID is also a significant challenge. These systems produce huge amounts of information that must be properly processed and analyzed. The lack of efficient analytical tools or inadequate data management can limit the effectiveness of the entire solution.

Finally, resistance from employees who may be afraid of change or have difficulty adapting to new technologies may be a barrier. This attitude may impact the pace of implementation and require additional communication and education efforts about the benefits of RFID implementation.

Overcoming these barriers will require appropriate planning, technical support and education at every stage of implementation so that the technology can bring maximum benefits to the analyzed enterprise.

5. Summary

The analysis showed that RFID technology plays an important role in warehouse and inventory management in a manufacturing company. The implementation of this solution resulted in the automation of key warehouse processes, which significantly improved operational efficiency, reduced the number of errors in the identification and management of goods, and increased the transparency of operations. The use of RFID enabled monitoring the movement of goods in real time, which contributed to a faster response to changing customer needs and better management of inventory rotation.

The analysis confirmed that the implementation of RFID allowed the elimination of many problems identified before the technology implementation, such as errors in documentation, improper use of warehouse space or delays in order fulfillment. The RFID system also enabled optimization of the use of warehouse space and better inventory planning, which reduced the risk of excesses and shortages. The use of this technology also contributed to increased customer satisfaction thanks to timely execution of orders and improved quality of delivered products.

The analysis also identified barriers and limitations related to the implementation of RFID, such as high initial costs, the need to modernize IT infrastructure and the need to conduct staff training. Despite these challenges, the benefits of implementing this technology significantly outweighed the implementation difficulties, which proves the great potential of RFID in warehouse management.

The research results allow us to conclude that RFID technology can become a key tool supporting enterprises in achieving greater operational efficiency and flexibility. Based on the conducted analyses and identified limitations of RFID technology implementation, it seems reasonable to focus future research on several key areas. First, it is recommended to conduct comparative studies in various industries, which will allow for assessing the scalability and effectiveness of RFID implementations in different operating conditions. In particular, it is worth paying attention to the adaptability of the technology in small and medium-sized enterprises, which may have limited technological and financial resources.

Another important area of research is the integration of RFID with advanced analytical tools, such as predictive systems, big data or artificial intelligence, which can significantly increase the level of automation and precision in inventory management. In addition, future analyses should include the impact of RFID on relationships with partners in the supply chain, with particular emphasis on data synchronization and operational transparency.

It is also worth undertaking research on the impact of RFID implementations on sustainable development, including reducing material losses, better use of resources and improving working conditions. The above directions should be supplemented by the identification of success factors and the most common implementation barriers, which will enable the development of effective implementation strategies tailored to the specifics of a given.

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