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Implementation of Barcode Technology to Logistics Processes of a Company

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Abstract: The article focuses on expanding the use of barcodes in selected logistics activities in a company. Our study discusses the application of barcode technology to selected logistics activities in the company in order to address the error rate in these activities and to control ownership of this technology in other logistics activities within the company during the COVID-19. The priority of the testing phase was to point out the elimination of errors in the original versus the newly proposed solution for the company on 10 products. In the test phase, the 10 products with the highest turnover in the company were used to point out the elimination of errors in various logistics activities, especially the time saved compared to the work of human personnel in the company. The company has this technology at its disposal, in the parent company as well as in the subsidiary. It was only a matter of expanding the use and applicability of this technology as well as other possibilities for research hypotheses, which we outlined at the end of the article. In this article, we focus on RFID and barcode technologies, since the company initially considered using RFID technology, however, chose the use of barcodes because it was an already known work technology. The current situation affected with COVID-19 disease requires many advantages and disadvantages of both technologies.

Keywords: RFID technology; barcode; comparison; company; production

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1. Introduction

The RFID (Radio Frequency Identification) technologies arose after 2003. They improve the effectiveness of many processes. Thanks to automatization, it is possible to save a lot of time. These technologies also have some vulnerabilities that we should consider during their application. By its very nature, automated identification has the potential to expose its subject to privacy and security risks. Literature [1] identifies these specific vulnerabilities associated with barcodes and RFID technologies and discusses ways to address such risks.

To supplement the theoretical knowledge in the literature on these two technologies, we have used a study by the University of Bristol entitled "A Comparison of Barcoding and RFID Technologies in Practice." This study compares RFID technology and barcode technology used by an unnamed company in their refrigerated warehouse. The company currently provides a comprehensive supply chain solution for several companies in the EU. The Marks & Spencer Company contacted this unnamed company and requested RFID technology introduction into its food supply chain. This chosen system replaced the existing barcode system. After the RFID technology implementation in one of the refrigerated warehouses, it was possible to prepare a comprehensive study [2].

The paper describes the information gathered from the company, the method of collecting data, then the evaluation of the information obtained by the test phase of the barcode implementation and the start of the test phase on the ten cables. We described the results of the measurements and the error rate in the Results section of the paper. The discussion and conclusion include evaluation, other possible measurements, and answering the hypotheses.

The study focuses on the operational performance of the technologies as scan cycle time and device failure. Data were collected in the refrigerated warehouse using time and motion studies of employees using RFID and barcode technology to scan products shipped in stackable plastic trays. Operator uptime was measured using a stopwatch for each scan cycle. The cycle began by activating the scanning device and ended by successfully scanning a stack of plastic trays. Measurements lasted during the morning shift between 7:00 and 9:00 on Sunday, Monday, and Tuesday. As part of the sample size selection, 20 warehouse employees were selected. These fully trained employees performed barcode and RFID scanning. Their age ranged from 21 to 48 years [2].

The following table (Table 1) shows scan cycle times measured over the monitored days divided according to the used technology.

Table 1. Results of scan cycle times for monitored days. Source: [2].

Day and Used Technology	Number of Scanning	Min. Value (s)	Max. Value (s)	Average (s)
Sunday—RFID	80	5.0	15.7	9.520
Sunday—barcode	80	18.4	35.4	24.895
Monday—RFID	60	5.2	15.7	9.182
Monday—barcode	60	15.3	31.2	24.167
Tuesday—RFID	60	5.0	16.8	10.357
Tuesday—barcode	60	18.5	32.6	24.237

Based on the measurement results, we can say that the average time of one cycle when operating with RFID technology was 9.669 s and, when using barcode technology, 24.479 s.

Observations of time and motion studies have revealed that many problems affect the timing of RFID and barcodes that have been difficult to predict. The difficulties of RFID technology were the following [2]:

- non-functional RFID equipment and tags;
- usage errors related to the RFID antenna;
- errors when scanning the entire stack of plastic trays;
- incorrect identifiers in the tray (it leads to a warning sound then the operator looks at the screen and stops scanning).

The issues found with the barcodes were [2]:

- missing labels on the outside of the plastic tray;
- illegible labels on a plastic tray;
- non-functional scanning device;
- a usage error in which the operator scans the barcode incorrectly or slowly.

It is clear from the previous figures that different errors occurred with both technologies. As part of the monitoring, 200 measurements were performed. There were 91 errors in barcode scanning. It means that the error rate for barcodes was 45.5%. With RFID technology, the error rate was 46.5%, which represents 93 errors. It suggests that RFID is prone to more errors during the scanning process [2].

The study [2] shows that RFID technology more has more user errors than barcodes. In comparison, the RFID had 29 errors; barcode technology only had five errors. Perhaps this suggests the maturity of the barcodes that the company used several years before.

This study provides a comparative analysis of RFID and barcode technology in an organization with a refrigerated warehouse. The findings support the most current research about RFID. It can provide faster scan times than barcode scanning. On the other hand, RFID scanning is prone to failures of device and usage errors. Improvement of employee training can partially eliminate these failures [2].

Figure 1 shows the error rate when using RFID technology and Figure 2 includes the error rate of barcode technology.

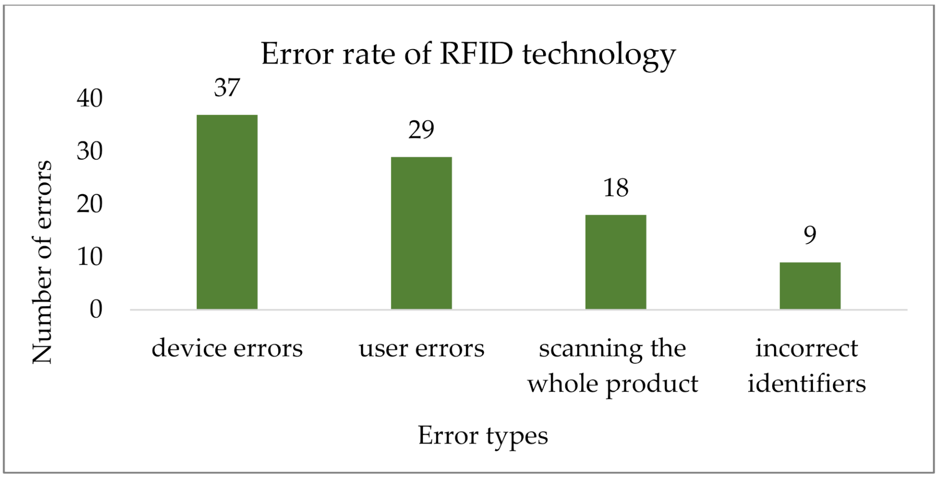

Figure 1. Error rate of RFID technology [2].

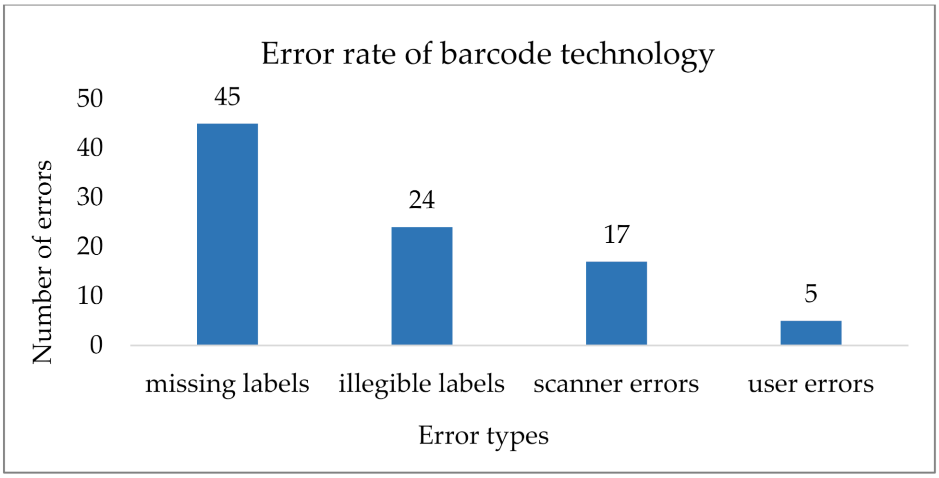

Figure 2. Error rate of barcode technology [2].

In article [3], the authors explain the change from the use of barcodes to radio frequency identification (RFID) in manufacturing logistics and point out the importance of barcodes for the future implementation of RFID. Based on two projects, they prove the interconnection of the use of barcodes and the RFIN system. The study mentions the potential consequences for future activities related to the introduction of an RFID system in production logistics [3].

This study [4] presented the application of RFID technology to increase the efficiency and effectiveness of warehouse management. The RFID system can quickly and simultaneously read multiple tags compared to sequential barcode reading with a handy barcode scanner for manual operations. Significant improvement was observed in preliminary experiments. The number of pallets and items processed by each operator per day increased by 425% and 438%, respectively. Data processing time in revenue and transport docks has been reduced by more than 90%. With RFID technology, it is possible to reduce the number of operators while maintaining the current capacity of services in the warehouse under study [4].

Radio Frequency IDentification (RFID) technology is a well-known wireless application for traceability, logistics and access control. It has become ubiquitous in industry and in our daily lives (ticket sales, payments, passports, car keys, etc.). RFID is now a standardized technology; its inherent benefits, which are unity, identification, or wireless communication, provide it with decisive practical benefits that drive new developments in concepts and applications. This trend is largely confirmed by the market forecast, but also its implementation in the field of health (smart hospital), assistance to people, as well as its perspective in terms of new paradigms of distributed environmental intelligence and the Internet of Things [5].

Currently, several RFID systems are commercially available for a number of applications, such as management control, transportation, supply chain, etc. However, the pooling of RFID tags and sensors could provide many new solutions to develop, in particular, green projects, such as more efficient energy production in chains, better waste control, recycling and other environmental challenges. In addition, the development of these new solutions requires the resolution of several technical issues addressed by the authors in Article [6].

The bar-code system currently in use on the market has a weakness in that identification is only carried out when the bar-code is visible. Unlike a barcode system, an RFID system uses radio frequency technology that allows for more accurate and faster identification of objects than a barcode system. RFID is a method of identifying object data using radio frequency technology by affixing a tag to identifying objects to be monitored. Recently, active research has been carried out and many attempts have been made to introduce RFID technology in the logistics and manufacturing sector. In Article [7], the authors present a method of checking the exact number of cells loaded in a truck using RFID technology. This research concerns the method by which an RFID reader and middleware are used to accurately and quickly count the number of RFID-tagged articles in real time. When the tagged articles reach the reader area, the information read by the reader is delivered to the middleware. The middleware then identifies the number of tags and displays the results to the user [7].

The RFID system has also found application in the rail transport of goods. Based on RFID technology and the proposed problems, the authors in Article [8] propose a well-functioning platform for managing railway package information. This platform can provide fast, highly efficient, intelligent, secure and stable solutions. The platform consists of five systems, which are a manual terminal system, a sorting system, a warehouse management system, a tracking system and a railway package management system. The implementation on the platform shows that it not only reduces the package transport cycle, but also improves the stability and security of the logistics management system. Multiple verification shows that the proposed platform has a very good practicality.

Although the RFID system is expanding and gradually replacing the use of barcodes, it will certainly not be limited. On the contrary, the need for barcodes is likely to increase due to their universal acceptance and ease of use with the low cost of barcode production (e.g., it is usually included in the cost of printing labels or packaging materials on products) [9]. As the population grows, so does the need to streamline and increase the safety of workplaces and their environment. Barcodes are used in supply chain management (SCM) applications in healthcare. The use of barcodes in healthcare facilities allows hospitals to save space and reduce overstocking by ordering necessary supplies on a daily basis [10]. In retail, barcodes are becoming part of smartphones with applications. Consumers can purchase and scan items through their phones. This makes it easy for the retailer to track consumer spending. Most manufacturing companies also turn to the barcode system. The use of barcodes in production plants helps to speed up and streamline the production process. However, as Table 2 shows, important advantages and disadvantages need to be considered for barcodes, as with all IT-intensive technologies [10].

Table 2. Selected advantages and disadvantages of barcoding as a part of identification technologies. Source: [10].

Advantages	Disadvantages
Inventory Control (through tracking and essentially error-free readings)	Costs (associated equipment and replacement costs)
Accuracy (2D, 3D Barcodes), Error reduction	Accuracy (especially with linear barcode)
Time savings	Limitations by line of sight scanning
Easy-to-use	Security issues, as they are easily read

Discussing the benefits of RFID technology only makes sense if compared to barcodes [11]. Important advantages of RFID over barcodes include the following [9,12,13]:

1. Speed—because an RFID reader can read tags faster than a normal barcode scanner can scan barcodes. For example, RFID readers designed for supply chain operations can perform up to 1500 read operations per second;
2. Reading distance—because it is common to read RFID tags at a distance of at least three meters between the tag and the antenna. Reading sizes and ranges are also compared with different RFID chips and the longest reading range in Article [14] is 14.6 m for a metal mounting antenna. Their passive UHF RFID tag had a range of 26 m for reading using the Higgs 4 RFID chip manufactured by Alien Tech.
3. Simultaneous instead of sequential scanning—because RFID readers can identify multiple tags in a reading field;
4. Direct view—because radio waves can penetrate most materials depending on the frequency used;
5. Durability—as RFID tags can work in extremely demanding working conditions and can be packaged in plastic packaging or even embedded directly into finished products [10,15,16].

However, barcodes can be easily printed or applied directly to products, and involve extremely accurate reading speed and very low cost [17–22].

Many authors compare the technology of using barcodes and RFID technology in the medical environment, specifically in the handling of medicines. In recent years, reference technology has moved to forensic techniques and systems that can transmit unique validated information over a distribution line to the point of delivery to a patient. Barcodes, 2D data matrix codes, tags and radio frequency identification (RFID) enable instant remote authentication, making it significantly more difficult for counterfeit products to enter the supply chain. These systems rely on a scanning and sending system, which means that, unlike the markings on the packaging, there is no interpretation of the information by the user; the remote device does all the work. Technology is relatively young and often expensive, and the reliability of some of its systems is still questionable, but it offers a significant opportunity to reduce the spread of counterfeit products if government agencies and medicine manufacturers adopt deviations from these strategies. They concluded that the medical tracking system is better in terms of safety when using RFID technology [23–26].

The effectiveness of bar-codes and RFID is also compared by other authors. Barcoding is an advanced technology of automatic identification (auto-ID), used in supply chain management (SCM) for several decades now. It enjoys free governance widespread application, especially in retail. Recently, however, radio frequency identification (RFID) has been considered a competitive technology that is excellent in its ability to store and update instant information as well as its non-line-of-sight (nLoS) reading ability. However, RFID is more expensive and, even if more convenient than barcoding, the current barcode is still the most widespread and widely used standard in the world. However, analyses have found that the need for barcodes in the supply chain will never really go away. What is being observed, rather, is a model of convergence, which suggests the need to integrate both technologies into the supply chain, all of which serve a common goal [27–30].

There are many discussions about the costs and benefits of implementing RFID in supply chains. As a result, researchers are finding an opportunity in the green field to explore how organizations can use technology in the context of the supply chain. The authors explore the potential benefits and limitations of RFID in a storage environment in two ways. First, it discusses issues related to pallet-level labelling and case-level labelling by creating a decision framework. Second, the knowledge from the framework is used to define an object-oriented modelling framework that facilitates warehouse simulation of RFID vs. interoperability barcode [31,32]. This simulation is used to examine some of the trade-offs between price and performance associated with six implementation strategies. The various strategies make important cost trade-offs and evaluate the statistical significance of the differences [33–35].

The unique features offered by radio frequency identification (RFID) technology distinguish it from other technologies, such as the Internet and EDI, and require further investigation, in particular related to its adoption. RFID is a wireless automatic identification and data acquisition (AIDC) technology [36] used to track shipments. RFID caught the attention of the media when giant retailers such as Walmart, Tesco, Target and Albertsons announced their intention to adopt RFID to streamline supply chain operations and demanded that their suppliers be RFID compliant. The literature on the adoption and use of RFID has demonstrated the high operational and strategic value of this technology [37]. Nonetheless, many potential adopters have not opted for RFID due to its implementation problems, including: infrastructure costs; environmental shocks; top management concerns; second-order organizational training; resource commitment; and organizational transformation. Most vendors have had difficulty adopting and using RFID technology cost-effectively for competitive advantage [35]. In addition, while previous RFID adoption studies have highlighted the importance of adoption mandates, especially in the early stages of exploring the potential of the technology, the importance of these mandates decreases over time, as perceived benefits and risks related to this technology are assessed [38].

Thus, the fact is that the adoption of RFID technology has been slower than expected, mainly because the hype associated with any new information technology (IT) [39] gave unrealistic expectations to researchers and practitioners [40]. Therefore, it is important to deepen our understanding of the various factors that determine the adoption of RFID technology by companies [35].

Although RFID technology brings many advantages over barcoding, it is necessary to look at its disadvantages. In Article [1], the authors identify a number of risks associated with the use of RFID, such as the risk of personal data protection and security. They consider the specific vulnerabilities associated with barcoding and RFID to identify related attack scenarios and discuss ways to address these risks and attacks [1].

As mentioned in the previous article, in this article [41] the authors are interested in all aspects of the introduction of RFID technology in business. However, any decision to adopt an RFID system without a clear and objective analysis of its effectiveness in an uncertain business environment carries serious risks. This article presents a tool for statistical analysis of the effectiveness of RFID compared to barcodes [41].

Despite the fact that RFID is making an impact on the world, for this technology's sustainability, it is necessary to think about reducing its price tag. Toward this end, scientists from around the world are working on chip-free RFID systems, though their use is not appropriate for every sector, as mentioned by the authors in Article [42]. For the purposes of conducting an examination of the possible application of the barcode and RFID system, this study focuses on the Thai timber industry, aiming to identify the most favourable traceability technology as well. The results suggest that RFID is a more advantageous identification method in terms of efficiency and user acceptability. However, the cost of an RFID tag should be reduced. Barcodes are not suitable for wood products, at least in the context of the Thai wood industry, even if they are used for other purposes. RFID, on the other hand, provides several advantages throughout the supply chain compared to barcodes and other conventional identification systems [42–44].

The Fourth Industrial Revolution significantly changed the traditional way of managing supply chains. Applications of Industry 4.0 (I4.0) technologies, such as the Internet of Things (IoT) and artificial intelligence (AI) in various supply chain processes, have helped companies improve their performance. Procurement can be considered a critical process in supply chain management, as it can provide new opportunities for supply chains to improve their efficiency and effectiveness. However, I4.0 applications can be ex-pensive and may not be reasonably available [45].

Procurement digitization can provide significant opportunities for excellence in renovation operations. This article [46] focuses on Procurement Resources 4.0 for front-end applications and core technologies. Based on Resource Based View theory, this research examines the role of resources influencing procurement 4.0 to increase productivity in renovation operations and the performance of the circular economy. Survey data for this research was collected from working professionals in South Africa, and the results show that technological resources are needed in procurement 4.0, which in turn can increase productivity in refurbishment operations.

The findings of this empirical study [47] suggest that Procurement Strategy 4.0 positively influences buyer intent to optimize business processes. Second, Procurement Performance Control 4.0 positively affects buyer intent to optimize business processes. Third, the ability to process information mitigates the impact of Procurement Performance Control 4.0 on buyer intent to optimize business processes. Finally, buyer intention to optimize business processes plays a key role in improving the performance of the circular economy. The simulation results demonstrate the potential benefits of Industry 4.0 appli-cations in the circular economy procurement function.

In this research [48], the authors provide an overview of the system architecture and also define a protocol and a smart contract at each stage that stores data in a blockchain center. They implemented a decentralized database and authentication system that uses blockchain and smart contract technology; each protocol at each stage was designed to achieve data integrity and undeniable reporting. Their system is more flexible in terms of transport, more secure in the communication protocol and more difficult to manipulate and falsify data.

Blockchain technology is basically a decentralized database managed by a team. It has the characteristics of high reliability and high confidentiality and has good prospects for an effective solution to the problem of trust between the two parties. In short, block-chain information will be publicly verifiable and will not be manipulated, which provides solutions for traditional logistics. The proposed scheme also achieves data integrity, resilience, forward and backward secrecy, undeniability and mutual authentication [49,50].

2. Materials and Methods

The goal of our proposal is to expand the use of barcodes in the unnamed company. Barcodes facilitate the process of item ordering (cables) that consists of several activities. Employees use barcodes when picking cables for production and identification of correct production positions. It affects the entire ordering process.

We will use the current method for receiving cables to the warehouse and storing them in a specific position on the slotted angle racks. Figure 3 shows the main changes in the activities of the proposed method.

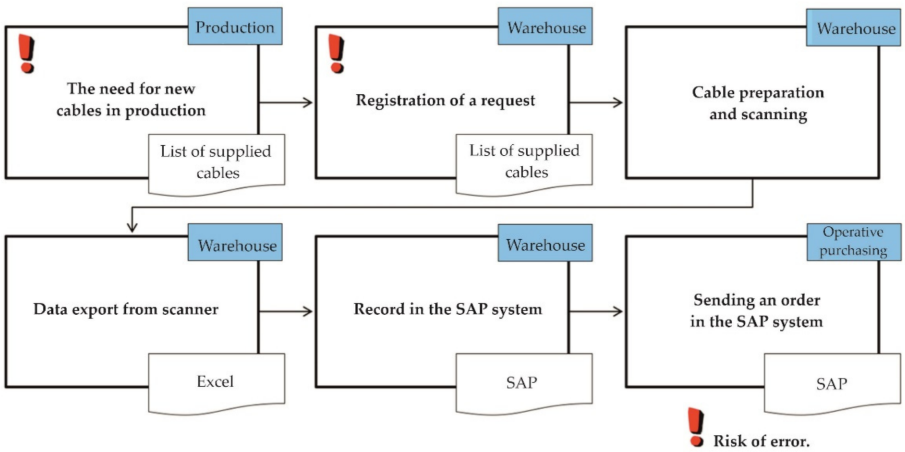

Figure 3. Sequence of activities in the proposed method of ordering cables. Source: processed by authors.

The process begins by ordering an item from production, where the production worker writes down the needed material in the specified table. Each material (cable) position in the factory has such a table. Warehouse workers check the entered requirements in production according to the schedule. They write down these requirements on a document, according to which they knows which cable to pick. In the warehouse, they first find the position of the item in the slotted rack and then load it onto a prepared pallet. Before being ready for production, workers must scan prepared cables with a scanning device. First, they scantheir personal barcodes, located on their ID cards. Then they scan the barcode of the workplace and the movement they want to make with the cable. For example, they scan the barcode labeled "STORAGE OUT" when picking up the cable. This barcode is in various places in the warehouse. It is also on a forklift to speed up the work of the warehouse employees. They then scan the barcode located on the cable reel label. This label is adhered to the cable when it is received at the warehouse. After scanning the barcode, workers still enter the amount of cable on the spool. This quantity is indicated on the packaging. Figure 4 shows the spool label with the barcode.

Figure 4. Scanned barcode on a spool of cable. Source: authors.

Then the employees can move the cable to the specified position in the factory. Before placing the cable in the correct place, they must scan the cable again. Each position in the factory has barcode labels. When employees stock an item, they must scan the position and movement barcode. At the end of the work shift, employees gives the scanner passes to the warehouse support manager. This person exports the collected data to a prepared database in Excel and performs a quick check of the data in the database with the help of preset macros. Based on the data from the database, it is possible to update the data in the SAP system. The SAP system then automatically evaluates the need to order cables, which reduces workload. Operational purchasing employees check the generated orders, set the date, and send them to the customer. We analyzed the main errors that arose during ordering cables. We also measured the duration of individual activities in the process. We used this data to design a new way of ordering.

With the current state of the cable ordering process, problems arose, especially with multi-stage manual recording, checking the current cable balance in the warehouse, and creating orders. They occurred due to an incorrectly entered balance from the warehouse or an incorrect quantity order. Based on the analysis of the error rate, we can highlight the most common errors:

- incorrectly entered balance from the warehouse;
- ordering the wrong quantity;
- error when entering data manually;
- differences between the actual stock balance and the stock level in the SAP system.

Many errors were connected with the incorrect amount of delivered material. Employees recorded information to the error record table. This information included the date, the material number of the cable, the number of unnecessary coils, the responsible person, and notes.

Warehouse support managers always send a table with the cables prepared for production before the end of the shift. They also write the balance of the item in this table. Errors can occur when warehouse managers check the cable balance on the rack. They can make a mistake when rewriting the table to Excel. In this case, the operational purchasing department has incorrect inputs. The second case can occur if the correct cable balance in stock is sent for an operational purchase, but an error occurs when evaluating the need for an order.

Another case is errors that occur when rewriting data in Excel. Employees do not record these errors anywhere. An error can occur in production, in the warehouse, and during its recording to Excel. Usually, an error occurs when the material number is incorrect. The operational purchasing department usually finds it. Subsequently, warehouse employees solve the problem; they find out what kind of cable it was.

The current method allows making a difference between the actual cable balance in the warehouse and the stock level in the SAP system. Responsible employees solve this problem by checking the stocks once a month and downloading the current state of the cables in the warehouse and the SAP system. They select the 20 most expensive cables with differences. According to the physical check of the cables, they adjust the data in the SAP system.

2.1. Measuring the Duration of Individual Activities in the Process

After analyzing the most common errors in the current method, the time of individual activities within the cable ordering process was measured. Before the measurement itself, it was necessary to determine appropriate activities that will be measured in time. The following activities were selected for measurement:

- registration of a request for documentation;
- picking cables for production
    - picking cables on a pallet;
    - cable transport;
    - placing cables;
    - checking (OK);
- rewriting the material for ordering and sending the list for operational purchase;
- copying the list to the cable order and evaluating the order;
- issuing an order in the SAP system.

The measurement was divided into three parts, according to who performed the individual activities. In the first part, the recording of requirements for documentation for production and the time of picking cables for production were measured. Due to the accuracy and usability of the results, the measurement of cable picking into production was divided into four separate activities, which were measured separately. These activities are handled by a warehouse workers who write the documentation requirements several times a day and prepare the cables for production. The measurement lasted for two days and a total of 4 measurements were performed.

In the second part, the activity of warehouse support managers, who are in charge of rewriting the material for ordering and sending the list for operational purchasing, was measured. This measurement was always performed at the end of the work shift within five days, with five measurements made.

The last part of the measurement was focused the work of operational purchasing. Four measurements were made over a period of four days. The measurement data were entered into a pre-prepared form, and then transcribed into and evaluated in Excel. Table 3 shows processed data from the whole measurement of individual activities in the cable ordering process.

Table 3. Measured data of current activities in the cable ordering process.

Responsible Workplace	Activity	Number of Cables (in Pcs)	Duration of the Activity	Time Required for 1 Cable	Average Duration of Activity *
Warehouse	Registration of a request for documentation	26	5 min 43 s	13 s	-
	Pallet picking	36	50 min 8 s	1 min 24 s	-
	Cable transport	-	-	-	1 min 11 s
	Cable documentation	36	63 min 30 s	1 min 46 s	-
	Enrollment (OK)	41	4 min 48 s	7 s	-
	Rewriting the material for ordering and sending the list for operational purchase	91	11 min 16 s	8 s	-
Operational purchasing	Copy the list to the cable order and evaluate the order	74	18 min	15 s	-
	Issuing an order in the SAP system	44	47 min	1 min 4 s	-

Note: (*) The average duration of an activity is the time calculated as the arithmetic mean of several measurements of the activity. This activity does not depend on the number of cables.

The measured values are added up for individual days and then model-converted to one cable. The measured value of cable transport is expressed as the arithmetic average of the duration of 15 measured cable transports. This activity cannot be expressed on a single cable because the warehouse workers transport multiple cables at one time. The number of cables per carriage depends on the size of the cable reel that is placed on the pallet. The special activities in picking up the cable for production will be the same in the proposed way. Therefore, after performing the measurement on the proposed method, the measured data of these activities were added up. The data for these activities are therefore more accurate and will not affect the results when comparing the current and the proposed method. Measured data of these activities in Table 4 are expressed over a period of five days, taking a total of 11 measurements.

Table 4. Conversion of measured data of current activities on one cable.

Responsible Workplace	Activity	Number of Cables (in Pcs)	Duration of Activity
Warehouse	Registration of a request for documentation	1	13 s
	Picking cables for production	1	4 min 28 s
	Rewriting the material for ordering and sending the list for operational purchase	1	8 s
Operational purchasing	Copy the list to the cable order and evaluate the order	1	15 s
	Issuing an order in the SAP system	1	1 min 4 s
The total time of the cable ordering process		1	6 min 8 s

In Table 4, the converted data per cable were recorded as well as the total time of the single cable ordering process.

The process of picking cables for production shown in Table 4 was divided into several activities for more detailed data. In Table 5 these activities were converted to one cable and added together. Finally, the total time of the process for ordering one cable was expressed, which is six minutes and eight seconds.

Table 5. Measured values in the proposed method. Source: processed by authors.

Responsible Department	Activity	Number of Cables (pcs)	Activity Duration (s)	Necessary Time per One Cable (s)	Activity Duration * (s)
Warehouse	Registration of a request	26	5 min 43 s	13 s	-
	Preparation of cables for production	36	50 min 8 s	1 min 24 s	-
	Scanning (warehouse)	20	7 min 57 s	24 s	-
	Cable transport	-	-	-	1 min 11 s
	Scanning (production)	20	7 min	21 s	-
	Cable unloading	36	63 min 30 s	1 min 46 s	-
	Writing (OK)	41	4 min 48 s	7 s	-
	Download from the scanner and copy to database	-	-	-	57 s
	Working with the database	70	1 min 41 s	2 s	-
	Record in the SAP system	-	-	-	30 s
Operational purchasing department	Sending an order in the SAP system	-	-	-	3 min 30 s

* The average duration of an activity is the time calculated as the arithmetic mean of several measurements. This activity does not depend on the number of cables.

2.2. Methodology for Time Measurements

We wanted to evaluate time savings when the factory used the proposed method of ordering cables. Therefore, we measured the duration of activities and then compared these values to those measured with the previous method. This measuring consisted of several parts, each representing different activity.

The first part of measurement focused on the work of warehouse employees. As in the original method, they prepare the cable for production based on production requirements. We performed seven measurements for operations carried out by warehouse employees over twenty-three days. Their activities were the same as in the original method, making it possible to put the results together and calculate one value from 11 measurements over five days. This can also ensure more accurate results. The proposed method adds scanning to the work of warehouse employees, which affects the cable preparation for production.

The second part of the measurement focused on the work of warehouse support managers. They download data from the scanner and update the database at the end of each shift. They check the data in the database and write down the values from the SAP system. We measured their activities over six days, with the measured data differing from the original measurement due to the activity changes of warehouse support managers.

We performed the last part of the measurement in the department of operational purchasing. Before the changes, its employees evaluated the stocked cables and placed orders accordingly. With the proposed method, all this is done by the SAP system. It automatically evaluates the need to order cables after usage in production. Employees only confirm the automatically generated orders, and sets the date. Then workers can send the order to the customer. This operation differs from the original method and, when we were measuring this activity, a problem arose during the test phase on ten selected cables within the monitored period. All these items were unnecessary in production.

Table 5 shows the measured values of the activities within the ordering of cables in the proposed method.

In our proposal, we added some tasks to the work of warehouse employees. They must scan cables during preparation as well as after sending the cables to a specific position in production. The cable transport duration remains the same as in the previous measurement. When evaluating the results of measuring the work of the warehouse support managers, we found that there are activities that do not depend on the number of cables. For example, the steps of downloading from the scanner, copying the data to the database, and working with the SAP system take as long for one item as for twenty cables. It is a similar case for operational purchasing, where the ordering in the SAP system does not depend on the number of items.

For a better comparison, Table 6 shows a model of recalculated data of activities in the proposed method for one cable.

Table 6. Measured values in the proposed method. Source: processed by authors.

Responsible Department	Activity	Number of Cables (pcs)	Activity Duration (s)
Warehouse	Registration of a request	1	13 s
	Preparation of cables for production	1	5 min 13 s
	Download from the scanner and copy to database	1	57 s
	Working with the database	1	2 s
	Record in the SAP system	1	30 s
Operational purchasing department	Sending an order in the SAP system	1	3 min 30 s
Total ordering time (proposal)		1	10 min 25 s

We then recalculated the measured data per cable. We found that the duration of the proposed method is four minutes and seventeen s longer than the original method. In the proposed method, consisting of three new activities does not depend on the number of cables. This means that, with more cables, it is possible the proposed method will be much more efficient.

3. Results

This part of the paper compares the original method of ordering cables to the proposal, a comparison made through error analysis and time measurement.

Probably the biggest problem with the original way of ordering cables was the emerging differences between the actual stock balance and the stock level in the SAP system. In the original method, warehouse workers wrote down the remaining amount of material after preparing the cable for production. Then the operational purchasing department received the data of consumption and material balance. After that, they could order the new material according to the balance in the warehouse. Problems arose when employees either entered the wrong stock balance or ordered the incorrect quantities based on the correct stock balance. Another problem was that the multiple manual entries of dataled to a high risk of mistakes.

In order to reduce the rate of error in their operations, the factory aimed to introduce entirely new technology into their procedures. Our proposal introduced a new method able to eliminate the mentioned errors, involving the cable having two positions, storage and production, and the warehouse support managers writing down the remaining amount of cables at the end of the shift. The latter is to ensure that the stock level in the SAP system is equal to the actual stock balance. During the phase of testing if and how the proposed method would work, and to reveal any unanticipated errors before implementation, employees still used manual data entry (using ten cables for testing). Starting the test phase on a single cable consisted of several steps. The scanning device is not connected to the SAP system, it is necessary to create a simple database in Excel, for the obtained data to be stored. Based on this database, the cables will be depreciated from the SAP system and used to check the correctness of the scan. Based on the data from the database downloaded from the SAP system, a cable with the sample material number 0612201 is selected for the turnover testing phase. This cable has the highest turnover. It was ordered 19 times in the previous year, while the preset amount of cable in one order is 15 000 m. Sometimes there may be another quantity in the order, usually in cases where the need is higher and the cable needs to be reordered. In the last step, the barcode scan itself started in the cable ordering process. When required to provide proof of the selected test cable, the storekeeper must pick up the cable on a pallet and scan the barcode on the package using a scanner. Other cables are prepared for production in the original way. Subsequently, before the end of the change, the head of the support department transfers the data from the scanner to the computer, copies of the data to the database and writes the given cable from the SAP system. All other cables will work in the original way. The process of ordering cables using a barcode is functional, but very impractical, because the storekeeper must be careful not to forget to select the selected cable. Therefore, this phase will not last long and the process will be extended to ten selected cables. Testing on ten cables is the last stage before the design of all cables used. The purpose of this testing is to fine-tune all activities so that they are ready to run fully. The reason for this between steps is to reveal shortcomings and problems that were not found when testing on a single cable as well as to resolve inconsistencies from the previous phase. The actual procedure for starting the test phase will be similar to one cable and will also consist of several steps.

For the test phase, it is necessary to select the other nine cables that have the highest annual turnover. The last step is to start the test phase on ten selected cables. In fact, it is a sharp test before applying the design to all available cables. The warehouse workers will scan all cables, regardless of which ones have been selected for testing. After downloading the data from the scanner, the warehouse managers will distinguish which cables need to be sent for the operational purchase and which need to be written off from the SAP system. In the testing phase, it is necessary to monitor the progress of the entire process and record all errors and problems that occur during the process. These will be the basis for further design development in the cable ordering process.

Due to the lack of data in the original method, we could not compare the error rate with our proposal. During testing after technological changes, only seven errors occurred. The test process took six days (142 performed scans). The error rate after the first six days of use was 4.93%.

We have divided the measurement of the individual activities into three parts. Some activities are the same in both methods, which means that the introduction of our proposal does not change them. Therefore, we have calculated an average value. In the proposed process, scanning has been added to the duties of warehouse workers. It was necessary to measure this activity. However, there are activities that no longer depend on the number of cables. We have expressed the duration of these activities as the average time from several measurements.

We have recalculated the measured data to one cable. On average, the factory uses 17 cable spools in one day. Table 7 compares the values of the original cable ordering method and the proposed method.

Table 7 shows values recalculated to one cable. The duration of the proposed method is longer by 4 min and 17 s. The right side of the table shows values of the processing of 17 cables (the average number per day). We have measured the time of transportation and other preparation activities separately. It is not possible to recalculate the time of transport to one cable. Warehouse workers can transport several cables at once. The number of cables per carriage depends on the size of the cable spool. Warehouse workers usually transports 6 to 10 cable spools at a time. In our calculations, we have supposed that they transport only six cable spools during one transport. It means that 17 cables need three rides. The average cable transport takes 1 min 11 s. The recalculation of the picking of 17 cables for production was therefore as follow:

- original method = (3 min 17 s × 17) + (1 min 11 s × 3) = 59 min 23 s
- proposed method = (4 min 2 s × 17) + (1 min 11 s × 3) = 1 h 12 min 7 s

The calculation of the average number of picked cables per day shows a time saving of 6 min and 23 s per day. This time saving arises thanks to the activities that do not depend on the number of cables. The proposed method of ordering cables is valuable with larger orders. If the production needs 17 cables per day, we can calculate timesaving for:

- one week 31 min and 55 s;
- one month 2 h, 7 min, and 40 s.

Table 7. Comparison of measured data of the original and the proposed method. Source: processed by authors.

Ordering Method	Responsible Department	Activity	Duration 1 Cable	Duration 17 Cables
Original	Warehouse	Registration of a request	13 s	3 min 41 s
		Preparation of cables for production	4 min 28 s	59 min 22 s
		Download data from the scanner and sending to operational purchase department	8 s	2 min 16 s
	Operational purchasing department	Copying data list to order and order evaluation	15 s	4 min 15 s
		Sending an order in the SAP system	1 min 4 s	18 min 8 s
	Total time of cable ordering process		6 min 8 s	1 h 27 min 42 s
Proposed	Warehouse	Registration of a request	13 s	3 min 41 s
		Preparation of cables for production	5 min 13 s	1 h 12 min 7 s
		Download from the scanner and copy to database	57 s	57 s
		Working with the database	2 s	34 s
		Record in the SAP system	30 s	30 s
	Operational purchasing department	Sending an order in the SAP system	3 min 30 s	3 min 30 s
	Total time of cable ordering process		10 min 25 s	1 h 21 min 19 s

We propose to increase the use of barcodes in the company. This company has already established barcode technology, but intelligent solutions can ensure the modernization and further development of the company. The proposal elaborates the process of changes, error analysis, and measurement of the duration of individual activities. Barcode technology was implemented into the process gradually, using two test phases.

We have performed the first phase on a single cable after thorough preparation. First, we created a simple database in Excel to store the data collected from the scanner. It was also necessary to prepare technical equipment. The company bought a scanning device to collect the scanned data. It was also important to mark the warehouse workplace with a bar code. The last task was to flip the selected cable to two positions in the SAP system. We also performed the second testing phase on another nine spools of cable. Again, several preparatory steps were necessary. We modified the database due to the larger data volume. Macros and other functions in Excel make this step faster. Due to increased inspection, we have marked each position in production with a barcode. Subsequently, we have flipped selected cables into two positions in the SAP system. This test was the last stage before implementing the proposed method on all available items. During the test, warehouse workers scanned all cables when picking. Subsequently, warehouse support managers had to distinguish two types of items. The first group was cables ordered via SAP system, and the second was cables sent for operative purchasing (original method).

We also prepared a detailed analysis of the error rate and duration of activities in the factory. Then we could compare the original way of ordering cables with our proposal. We have eliminated almost all mistakes and problems that arose in the original method with barcode technology. Flipping the cables to two positions in the SAP system resolved the emerging differences between the actual stock balance and the stock level in the SAP system. Our proposal partially resolved multiple manual data entries with a high risk of error. For some activities, however, warehouse workers must still manually enter the data into the prepared form. In the future, we can also resolve this problem by introducing the pull-out principle from production via the SAP system. We could not express the exact error rate in the original method due to a lack of data. However, we can determine the error rate in the proposed process. During the six days after the test phase, employees performed 142 scans with seven errors. Errors occurred due to incorrect scanning and subsequent incorrect database settings. The error rate after the first six days of use was 4.93%.

After the introduction of the proposed method of ordering cables, the error rate was also monitored, which was recorded and evaluated every day. The error rate was checked every day after downloading data from the scanner in the database. Data are only available for the first six days of use to prepare and evaluate the analysis. In the company, monitoring and evaluation of error rates will continue, as this is one of the basic indicators when introducing a new proposal. When monitoring the error rate, errors were formulated that occurred or may still occur in this way. The following basic errors were made:

- scan error—incorrectly entered length;
- scanning error—writing in the wrong field;
- scan error—no input or output scan;
- scanning error—the same operation scanned 2 times;
- incorrectly ordered cable quantity;
- database error.

When checking the data in the database, it may happen that there is a difference between the agreed and the actual amount of cables. The reason is that the company that supplies the cables does not always send the exact and agreed amount of cable on the spool. In this case, the storekeeper enters the quantity that is on the package during the scan, and during the subsequent check in the database, the difference between the quantity actually scanned and the quantity that was agreed upon is marked. The agreed number of cables from the SAP system is generated in the database for inspection. This difference will not be considered a mistake, as this problem also occurred in the original way and is not related to the introduction of barcode technology into the process. The reason for this error may also be an incorrectly ordered amount of cable. Since only 10 cables are currently being tested under the proposed method, the other cables are ordered in the old way. This means that the need to order a cable must be evaluated in an operational purchase. Once the proposed method has been implemented on all cables, this error will no longer occur because the need to order a cable will be automatically generated by the SAP system. Excel database errors can also be a problem. Some macros and formulas may not always work correctly, or some material numbers may not have an agreed number of cables. This means that the control will not work.

Another group of errors are warehousing errors when scanning barcodes on cables. Warehouse workers may enter the wrong cable length or inadvertently scan the data into another field. Warehouse workers scan the cables when picking them up for production, but also before documenting the cables in the specified position. Just by double-scanning the cables, this error rate could be minimized. Nevertheless, the warehouse workers may forget to scan the cables, either when picking or documenting the cables for production. Alternatively, it accidentally scans the cable twice.

First, we measured individual activities with the original method. We performed 13 measurements in 11 days. After the introduction of the proposed method, we performed another 13 measurements for nine days. The measurement data were then processed and evaluated in tables. For better comparison, we calculated the time required for one cable. It was necessary to determine the average number of used cables per day to find out how much time the company will save per day. On average, production sends 17 cables per day. We calculated with 17 cables and then compared time savings (Table 8).

Table 8. Comparison of total time of cable ordering process. Source: processed by authors.

Ordering Method	Total Time of Cable Ordering Process	
	1 Cable	**17 Cables**
Original	6 min 8 s	1 h 27 min 42 s
Proposed	10 min 25 s	1 h 21 min 19 s
Difference	4 min 17 s	6 min 23 s

4. Discussion

Barcoding is a technology that is currently one of the most used technologies on the market of Slovak manufacturers, logistics companies and, last but not least, distributors. It results from its affordability. It also offers easy implementation within the entire logistics chain. If we consider the speed and possibility of processing a large amount of data, RFID technology is better. Currently, RFID is used only in companies that need to process a large amount of information. The barcode technology is used in smaller companies because it is more affordable. We should mention that barcodes have possible limitations in terms of visibility, accessibility, processing quality, readability, and delays in barcode processing. The RFID technology can avoid these disadvantages. It is possible to process more RFID tags in one moment without direct visibility. It is not yet possible to read the RIFD tag in liquid or on any metal. We cannot forget that RFID technology installing requires technical and technological equipment. It is essential to have experience with the implementation of this technology in the entire logistics chain. The advantage of RIFD in one department of the company is debatable if other departments will not adapt to it and accept these technical and technological means.

Radio Frequency Identification Technology was developed as a suitable alternative to barcode applications. These two technologies complement each other. Despite the spread use of RFID, many factories still use barcodes [1,2].

Compared to a barcode, RFID has a higher scanning speed and lower operator requirements, so it is easy to apply in automated systems. The big difference is that the barcode needs direct visibility between the code and the scanner to scan it. Scanning is, therefore, more damning for the operator who orients the barcode to the scanning device. RFID technology does not require direct visibility between the tag and the reading device. Therefore, the reading device can scan all RFID tags which are within range. Another difference is that the barcode scanner uses a laser or other optical sensor. RFID reads information from the tags via radio frequency waves. Due to low label prices and established standards, barcode technology is significantly widespread. RFID technology is used only in some specific cases [2].

The basic differences between the barcode and RFID technology are summarized in Table 9.

Table 9. Basic differences between barcode and RFID. Source: [1].

Evaluated Properties	Barcode	RFID
Coding	Coding by color contrast between vertical lines and spaces	Coding in electronic form
Time	Scanning takes a few minutes	Scanning takes a few seconds
Scanning	May not load or scanned twice	It cannot be unloaded or duplicated
Information	Information on the type of product	Information on the type of product, packaging, production date, origin, price of the product, date of dispatch and consumption
Visibility	Direct visibility	Does not have to be direct visibility

5. Conclusions

By introducing barcode technology into the cable ordering process, the company used its potential and used the already established technology. Figure 5 shows the benefits of the proposed method and its comparison with the original process. Our proposal made the process simpler and faster. Barcode technology also can reduce the error rate in the process. In addition, there is a possibility of further development and modernization of the company. But other opportunities arise from the introduction of technology into the cable ordering process. These possible benefits of the proposal in the future may are:

- extending the proposed method to all available items;
- implementation of the data on the length of the cable on the spool into the barcode;
- setting up a regular inventory;
- introducing cable scanning also when receiving cables;
- regular monitoring and analysis of error rates;
- automating the database and its checking;
- introduction of the pulling principle from production.

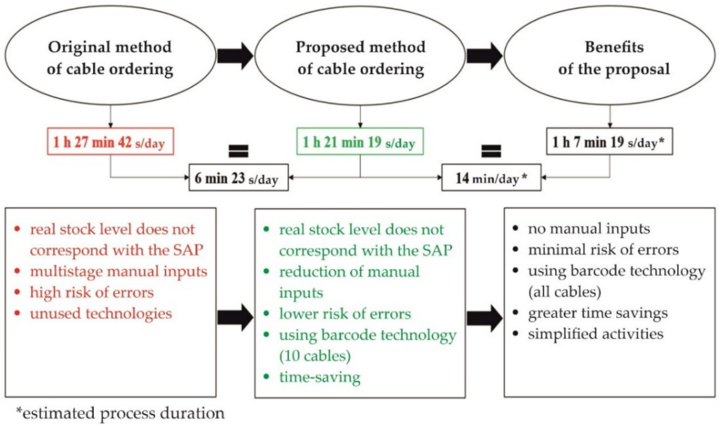

Figure 5. Evaluation of the proposed method and future benefits. Source: processed by authors.

By extending the proposed method to all available cables, the activities in the process will be unified and clear. Then the employee will no longer use two different ways of picking cables. The factory extended our proposed method to all available items after one month of testing. Measured data from the testing phase can help with the identification of opportunities for further improvement. We can also implement the cable length information from the spool into the barcode. It will also reduce the time necessary for preparing cable for production. Negotiations are currently underway with the cable supplier to put this option into use.

The advantage of the proposed method is the simplification of the work of employees in the warehouse and on operational purchasing. Another advantage is the reduction of mistakes in the process. Moreover, the proposal also eliminated problems with cable balances in the database and in the warehouse. The main benefits include: no manual entry, minimal risk of mistakes, use of barcode technology, greater time savings and simplification of activities.

Furthermore, the company will introduce the regular cable inventory, based on which the company will have information about stock level. The idea of scanning barcodes could also be an improvement when receiving materials. It would require another database of received cables linked to the current cable database.

It also will be necessary to monitor and evaluate the errors that have occurred. This comprehensive information helps to prevent further mistakes. We have analyzed the error rate for 16 days (six day start phase, 10 day test phase on 10 cables). We found that the most errors occurred due to a poorly set up database. Therefore, it is necessary to continue to check the database and try to automate the work in it as much as possible. Automating work in the database can result in additional time savings. The introduction of the pulling principle from production can bring a positive change to the whole process. Management considered this option already during the test phase. The operation principle is quite simple. Production workers will scan the barcode on the empty cable spool they want to provide. The scanning device will have a direct connection with the SAP system. It would work in the so-called online mode. Warehouse workers would no longer have to go to production and check the requirements in the table. As part of the daily schedule, they would check production requirements in the SAP system. After scanning the cable when preparing for production, this requirement would disappear in the system. The pulling principle requires a thorough preparation of the information system and the acquisition of new scanning devices. However, it can bring significant simplification of work and save time.

The verification of the result consists of the elaboration of our study on one example of a cable harness for the subsequent launch of the test phase of the implementation of barcode technology at all workplaces with cable harnesses. The company expressed satisfaction with the measured values and maybe only time will tell the correctness of the barcode implementation. The limitation may be the use of only 10 other workplaces, as the research focused on only one workplace and on the most ordered cable harness in the company. The high turnover of the given cable harness at the workplace where the test phase started, which is where orders for this type of cable placed, renders sufficient verification of the correctness of the procedure. Of course, only time can verify the correctness of the barcode technology used, as trends in this area are constantly changing, mainly during the COVID-19 pandemic. Furthermore, the company's headquarters uses bar codes, and the subsidiary wanted to go in the same direction; therefore, using this technology would also make several logistics operations easier. Nevertheless, in the conditions of the Slovak Republic, greater satisfaction with 2D codes is currently being demonstrated, as many products are too small and have problems with the placement of the bar code and the RFID chip. We can substantiate this statement by communicating with the company's representative with Kolarovszki Peter (GS Slovakia).

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