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Simulation of product indetification technologies in storage systems

Abstract

Barcode and Radio Frequency Identification (RFID) as identification technologies are widely used in warehouses of the logistics supply chain to track and locate storage units, track manipulation equipment and the state of storage locations. Depending on the needs and design of the warehouse and the way its operations are executed, one identification system can be used more frequently than the other. The identification system influences how logistical processes in the warehouse are performed, and it is often integrated with some form of the Warehouse Management System (WMS). The correct choice of an identification system influences data accuracy, resource utilization, waiting times for process execution and overall efficiency. This paper aims to show specific differences in the use of barcode or RFID technology, on the example of the reference warehouse system. Two warehouse logistic processes (storing and issuing of products) are described and modelled with the BPMN, to define all the process elements. Then, process simulation models are created, and both barcode and RFID systems are tested in the process simulation experiments. The simulation results enable the comparison of key performance indicators, based on the required process and waiting time for checking goods which flow through the system and the utilization of the material handling equipment.

Keywords: warehouse management, storage processes, barcode, RFID, BPMN model, simulation

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Introduction

The application of information technology in logistic processes is immense and includes the use of different hardware and software. Logistic companies use information technologies to track their business in real-time through the supply chain. Logistic information systems such as warehouse management systems (WMS) are used for the planning, tracking, and control of logistic process execution. The successful use of a warehouse management system needs to be supported with information from different sources. Most of this information comes from barcodes or RFID tags.

Barcode and RFID technologies are widely used in the logistics supply chain; the warehouse storage locations are labelled with barcode or RFID tags just like storage units from pallets to single products. Warehouse operators are equipped with different reading devices which are also found on manipulation equipment, and various locations such as warehouse entrance or exit docks. The existing warehouse design and its environment need the right combination of equipment, human resources, data sources, and a control system.

Theoretical background

The barcode represents a technology for storing information in a one-dimensional pattern to represent digits, which can be read via a scanner for further processing (Fan et al. 2019). Besides one-dimensional (1D) barcodes, there are two-dimensional (2D) barcodes, often epitomized in the form of QR codes which can store more information (Lotlikar et al. 2013).

RFID represents a wireless technology for the identification of objects via tags (Duroc–Tedjini 2018). Besides tags, the RFID system also includes a reader for reading the information contained on a tag, a database for information storage, and further processing from software applications (Duroc–Tedjini 2018). Types of RFID tags are active and passive. Active tags possess an energy source used for information emission, and passive tags use the energy of the RFID reader.

Barcode information can only be read, while the RFID tag supports read and write operations so the information on them can be modified if needed. Barcodes are considered to be a less costly technology than RFID, but the RFID tags have more storage capacity than barcodes (Lotlikar et al. 2013). Also, RFID tags endure high-humidity and high-temperature environments much better.

There is a lot of research describing the implementation of barcode and RFID in appropriate situations. Besides their item identification role, barcodes are successfully implemented for warehouse operations management. Barcodes are used for inventory management (Wanitwattanakosol et al. 2015), for locating the warehouse autonomous mobile lifting robots (Wurman et al. 2008), and also for the optimization of the spare parts warehouse control process in combination with the cloud application (Muyumba–Phiri 2017).

Previous research reports that the application of barcodes in warehouses result in fewer errors and better warehouse management. Regarding RFID, the implementation field is even more extensive. Besides locating products in the warehouse (Tejesh–Neeraja 2018), there are also other applications of this technology in the warehouse, as described in Zhou et al. 2017, where it is reported that RFID was used to track storage shelves. The introduction of the RFID technology supported the decision management system and reduced transportation costs and lead time.

Nowadays, RFID technology is often used in combination with other technologies such as sensors, drones and blockchains. In the case presented in Fernández-Caramés et al. 2019, RFID is combined with drones and the blockchain technology to automate warehouse inventory processes. The performance testing results have shown a significant improvement in the speed of carrying out warehouse data collection and locating items in favour of the automated system vs the speed of an operator. Alfian et al. 2020 describe the use of RFID in combination with IoT sensors to track perishable food items. The authors report the successful application of the integrated system in which RFID helps track the movement of the goods and the IoT sensors monitor parameters like humidity and temperature. Another example is presented by Helo–Shamsuzzoha 2020, where RFID is combined with IoT and blockchain technology to enable the system which helps to track goods through the supply chain in real-time.

Which combination of the mentioned technological elements (barcode, RFID) proved to be time and cost-effective and also efficient for warehouse-process performances? There has been previous research on this exciting subject. For example, Bertolini et al. 2012 studied the implementation of RFID in the apparel supply chain and proved an efficiency increase in logistic processes. The as-is process included barcodes for item identification in logistic operations. The implementation of RFID increased efficiency of the re-engineered shipping process and the item scanning operations. Another study, Morenza-Cinos et al. 2019, carried out performance comparison between robot-assisted RFID item identification and manual RFID item identification (with the use of a handheld computer) in the library and retail department. The research results show that the robot-assisted RFID item identification resulted in increased information accuracy compared to the human one, who performed the same job using the handheld computer. Moatari-Kazerouni–Bendavid 2017 investigated the performances of the logistic process for surgical instruments. The as-is process included 1D barcodes for individual item identification and 1D and 2D barcodes for storing the item set information. The authors presented potential to-be scenarios with the use of simulation (scenarios include the RFID system or a combination of barcode and RFID). Their simulation results show better human resources efficiency, lesser human resource costs and shorter process times when the RFID is used, and the per cent of usage of the surgical items is better when the barcode is applied.

Having considered previous research efforts, the research presented in this paper gives some insight into simulated warehouse process performance when the RFID or barcode technologies are applied in the same example case.

Methodology

This paper examines the case of a warehouse designed for pallet storing. Warehouse process mapping is performed, covering the use of barcode and RFID. First, the process-mapping via modelling language helped to understand all the necessary process steps after which, the simulation parameters were set up.

Two different technologies for the tracking of goods and the barcode and RFID applied to a simulation model of the storage system were compared in the simulation. For this purpose, the material flow simulation software Enterprise Dynamics was used.

For the process mapping and simulation, the general example of the pallet warehouse is used, as it covers the most common situations found in real systems.

The performance parameters for the given examples are the result of the computer simulation of these processes.

The simulation results were analysed by comparing the performance indicators for both types of systems for the product storing and issuing processes.

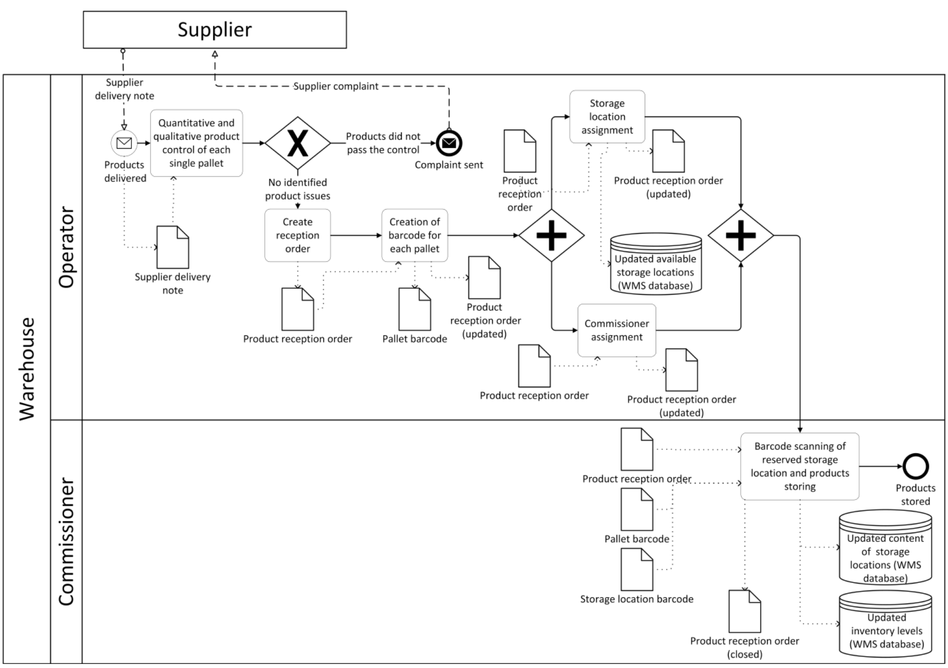
Research findings

Process modelling

Process modelling was performed with the BPMN modelling language (von Rosing et al. 2015), which allowed us to map the process as a set of connected events and activities. Activities can be additionally connected with organizational and information resources. Logical gateways were also used (and, or, xor) for process flow branching, supporting the parallel flows, decision making, and loops. There were two setups to be discussed here. First, the process was supported with barcode only, and second, where the process was supported with RFID technology. The models for product storing and issuing processes supported with barcode are presented in figures 1 and 2, respectively.

Storing products in a warehouse storage location is a process made up of several activities. The process starts when the supplier delivers the products on pallets. The warehouse operator performs qualitative and quantitative checks. One of the steps during the checking is that each pallet needs to be scanned with the barcode reader. If the products do not pass the control, the process ends with a complaint addressed to the supplier. In another case, the reception order is created via WMS, and the pallets are barcoded for storing purposes. The warehouse operator assigns the storage location, and the available locations are updated in the WMS database. Also, the operator designates the picker, which will carry the pallet to the storage location. The data on the reception order is updated in each of the previous steps. The picker scans the barcode of the reserved storage location and the pallet and stores away the product. Storing of the products ends with the WMS database update (storage location content and inventory levels) and the closing of the product reception order.

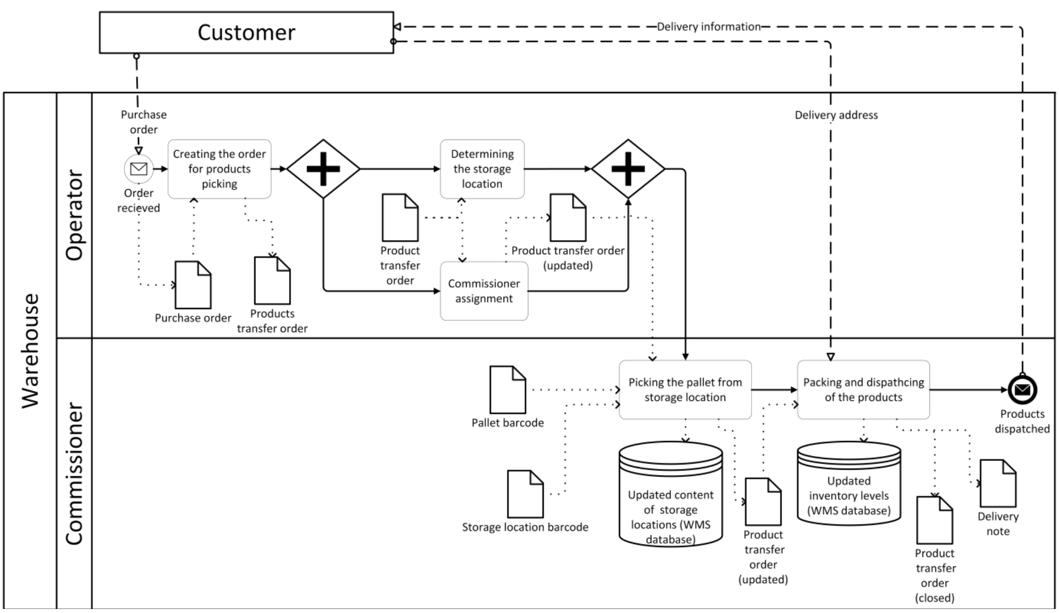
Figure 1: *BPMN model for product storing process with barcode applied*



The RFID technology does not change the process itself very much, but somewhat improves it. The single pallet scanning is now replaced with vehicle RFID scanning at the warehouse gates, thus enabling multiple pallet identification. The creation of individual pallet barcodes is eliminated. After the storage location and picker are assigned, the pallet RFID data is updated. Storage of pallets does not involve reading the barcode of each storage location and each pallet. The RFID tags enable remote reading of the data, thus updating the data for the WMS is simplified.

Retrieving and dispatching the products from a storage location is the second observed process. The process begins when the purchase order is received. Based on the purchase order, the operator creates a product transfer order in the WMS software. When the order is created, the operator uses the WMS software to locate the product in the warehouse and assign the picker. Then the picking operation can start. For product picking, the picker uses the barcode reader to read the storage location and pallet barcodes. After the product is picked the content of the storage location is updated in the WMS database, and the product transfer order is updated, too. Then come the packing and dispatching of the product. The inventory levels in the WMS database are updated, and the delivery note is printed and dispatched along with the purchased product.

Figure 2: *BPMN model for product issuing process with barcode applied*



If the process is set up with the RFID technology, the readings of the pallet and storage location data can be done remotely during the picking step. This makes the step less time-consuming. Also, the barcodes from the initial process setup are now unnecessary.

Simulations

Simulations enable observation of the entire system and detection of eventual irregularities, bottlenecks, and problems that occur in the material flow, as well as the testing and validation of potential solutions for their elimination (Živanić et al. 2019). Optimization of a storage system is a necessary step in the process of material flow optimization, primarily due to the relatively high costs it can generate in a supply chain.

Simulation software and simulation model

Enterprise Dynamics is a software for simulation of real-life issues of external problems, as well as for solving any complex problem related to people, processes, technology, and infrastructure (www.incontrolsim.com). The software can be applied in the following domains: automotive, electronics, manufacturing, materials handling, air transport, water transport, port terminals, rail transport, health care, banking and finance, public and services, supply chain management, logistics and distribution, sports and events, as well as for education. (www.incontrolsim.com).

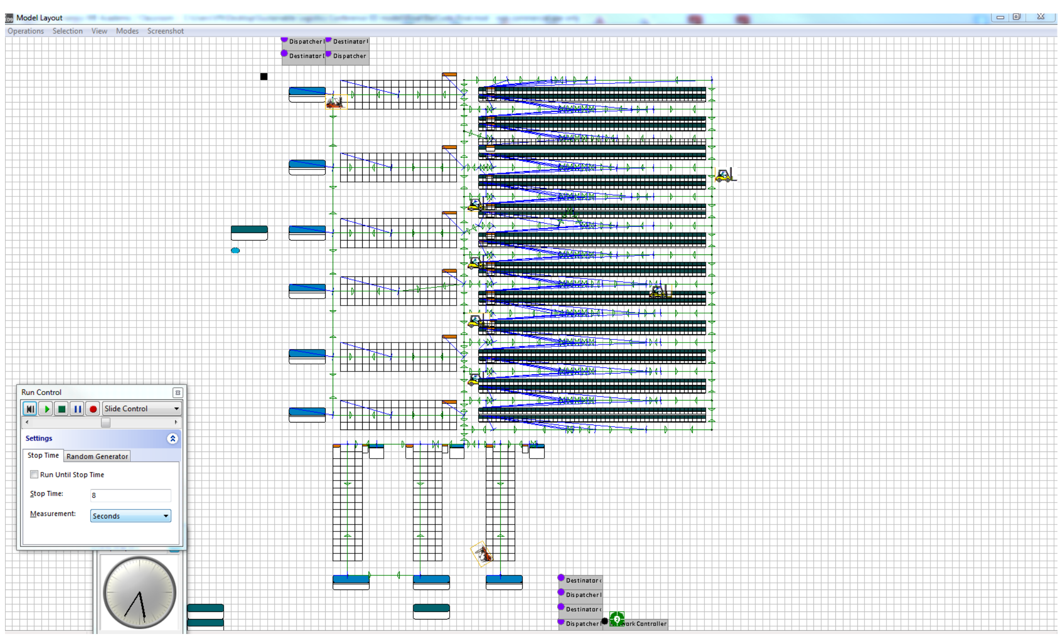
The example experimental storage system contains six entrance and three exit docks, conventional pallet racks for pallet storage, two forklift trucks and ten pallet trucks of cargo handling equipment in the storage facility.

The required handling equipment for pallets that arrive into the storage facility through the entrance docks is pallet trucks, just like in the case of the exit docks and the shipment of pallets from the storage. For handling internal transport and pallet manipulation, forklift trucks are used.

Figure 3 is a 3D visual representation of the storage system together with a window for adjusting the simulation flow, and the duration of the simulation clock, while *Figure 4* represents a visualization of the model in 2D.

Figure 3: *3D model view of the storage system*

Figure 4: *2D model view of the storage system*



In the storage system goods repeatedly arrive by a normal distribution of 3 hours with a deviation of 1 hour at the time, within 32 pallets per truck. The pallet trucks carry pallets into the entry zones of the storage, with each of pallets with products passing through bar code (in the first simulation model) and RFID scanning (in the second simulation model). After that, the forklift truck picks them and brings them into the storage area to a predefined pallet place by WMS. When the ordered product needs to be taken out from the storage area, the pickers carry the required products (articles) and put them into the pallet truck. In the exit zone of the storage area, a pallet unit with required products is created, and it is also checked out from the storage by barcode or RFID technology.

Furthermore, a pallet unit is prepared to be carried to the exit dock by a pallet truck. The load and unload time set for the handling equipment is defined by normal distribution. The time set for the pallet trucks that carry pallets into and out of the storage area is 10 seconds with 5 seconds deviation. Forklift truckload time is 10 seconds with a deviation of 5 seconds, unload time is 20 seconds with 10 seconds deviation. Concerning the storage system with applied barcode technology, the picking forklifts load time is 15 seconds with 5 seconds deviation, and unload time is 7 seconds with 2 seconds deviation. In the case of applied RFID technology, the picking forklift has a load time of 7 seconds with a deviation of 2 seconds, while the unload time is 4 seconds with 2 seconds deviation. The time required for the identification of goods in the input and output zones also depends on the applied technology. Therefore, the identification time is defined by normal distribution, for applied barcode, it is 120 seconds with 20 seconds deviation, and in the case of RFID, it is 2 seconds with 1-second deviation.

Simulation results of the model with applied barcode technology show a relatively low level of forklift truck utilization in serving either the input zone of the storage area (40%) or the output zone (50%) *(Figure 5)*. Utilization of forklifts that carry pallets into the storage zone of the system is 86%. The pallet truck that performs the picking of goods from the storage zone is utilized in 100%, which includes about 60% of travelling full, i.e. with ordered goods, and the average time of waiting for products to pass through barcode scanning of 2.5–3 minutes.

Simulation results of the model with applied RFID technology show that a pallet truck serving the input zone of the storage zone has a utilization of 40% on average, depending on the arrival and quantity of goods *(Figure 6)*. Utilization of the forklift truck that carries pallets into the storage zone is 83%, which is higher than the results in the first simulation model. The pallet trucks picking the goods are utilized in 100%, including about 70% of travelling full, which implies higher picking efficiency where

RFID technology is used. Utilization of the pallet truck that serves the output zones amounts to 60%, which proves that with RFID technology the output zone accumulates products faster, and therefore, the utilization of the handling equipment is more efficient.

Figure 5: *Simulation results of the storage system with applied barcode technology*

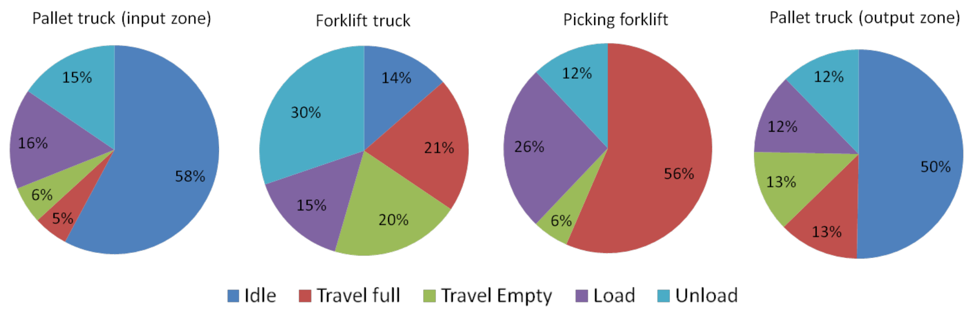
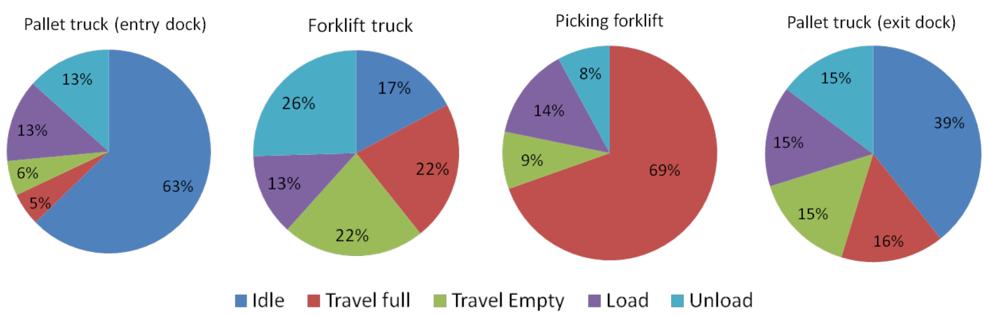


Figure 6: *Simulation results of the storage system with applied RFID technology*



Based on the parameter comparison presented in Table 1, several conclusions can be drawn. When applying the barcode technology, the time required for scanning the products that arrive in the storage zone depends partly on the number of goods that the pallet unit contains. In contrast, with the RFID technology scanning occurs simultaneously, and it is not dependent on the number or quantity of goods. Order picking efficiency per picker in case of RFID technology is 10% higher compared to the barcode because there is no need to scan every product (article) in the picking process, which indicates a significant saving of order picking time relative to barcode technology. Further, in this simulated storage system, the obtained result also implies that the optimal quantity of handling equipment, as well as pickers, are to be considered.

Handling equipment utilization at the output zone or dispatch zone is 10% higher when RFID technology is applied, as mentioned above. There is no waiting for the products to be scanned. The storage system simulation model with RFID technology also indicates that using RFID technology results in a 15–20% higher number of dispatched pallets from the storage.

Table 1: *Comparison of storage system simulation results*

	Waiting time at the input/ output storage zone	**Equipment utilization when picking orders**	**Equipment utilization when dispatching goods**	**Approximate amount of dispatched goods** (pallets/ week)
Barcode	2.5–3 minutes	60%	50%	5500
RFID	/	70%	60%	650

Simulation results also show that the waiting time of pallets to be placed at the storage area is 50% higher with applied barcode technology, and the processing time for dispatching goods is 73% higher compared to the RFID technology.

Conclusion

Storage systems are an integral part of each supply chain and significantly impact the total supply chain cost. Therefore, it is necessary to choose a product tracking system with which the warehouse can perform optimally regarding its capacity, utilization of equipment and other performance indicators.

It can be concluded from the above simulation of storage systems with applied barcode and RFID technology and having the same volume of goods flow, that with the use of the RFID technology time-saving through scanning, tracking and manipulation of goods, better utilization of handling equipment can be achieved, and there are also indications that less human resources are needed.

Further research may include the simulation of the system where each product is labelled with RFID or a financial analysis of both technologies, to check whether the usage of the RFID technology pays off in comparison to the barcode in this type of a system. Also, it would be interesting to simulate the performance of the storage process work operations when the RFID or barcode is applied together with other technologies (drones, robots, sensors).

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