EFFECTIVENESS OF AUTOMATIC IDENTIFICATION TECHNOLOGIES IN SHIPMENT CONSOLIDATION

[1]Jan CHOCHOLÁČ, [1]Roman HRUŠKA, [1]Dana SOMMERAUEROVÁ

[1]University of Pardubice, Faculty of Transport Engineering, Pardubice, Czech Republic, EU,
jan.chocholac@upce.cz, roman.hruska@upce.cz, dana.sommerauerova@upce.cz

https://doi.org/10.37904/clc.2022.4565

Abstract

The issue of distribution logistics including all sub-processes is very topical. E-commerce experiencing a great expansion every year, which has been exacerbated by the ongoing pandemic. As a result, there is increasing pressure to streamline distribution logistics processes within last mile logistics. One possible solution is to reduce the time of the shipment consolidation process by using automatic identification technologies (e.g., using radio frequency identification technology), as logistic service providers mostly use barcodes or 2D code technology for automatic data processing. The article focuses on the effectiveness of automatic identification technologies in shipment consolidation process. The aim of the paper is to find out what time savings the implementation of radio frequency identification technology can bring compared to barcode technology in the process of shipment consolidation. The analyzed automatic identification technologies are compared experimentally using the Laboratory of Automatic Identification at the University of Pardubice, Faculty of Transport Engineering. Subsequently, a shipment consolidation model is created in Witness Horizon software using a dynamic simulation that simulates the duration of the shipment consolidation process for different inputs and the automatic identification technology used. The main monitored parameter is the total duration of the shipment consolidation process for different model input parameters. The experimental and dynamic simulation results are compared in the context of other studies.

Keywords: Radio frequency identification technology, barcode, dynamic simulation, distribution logistics, last mile logistics

1. INTRODUCTION

The main goal of each business is to optimize all logistic operations to minimize errors and gain competitive advantage over other businesses in the industry [1]. Logistics is the part of supply chain management that plans, implements, and effectively manages the forward and reverse flows of products, services, and relevant information from the place of origin to the place of consumption and warehousing of goods to meet end customer requirements [2]. Logistic management is an integrative function that coordinates and optimizes all logistic activities, as well as participates in the connection of logistic activities with other functions, including marketing, production, sales, finance, and information technology [2]. With the rapid development of the economy, the development of logistic companies around the world is facing a major challenge; in particular, logistic companies generally lack basic competitiveness, efficient logistic processes and awareness of service innovation is not strong [3].

Distribution logistics costs represent the highest proportion of total logistic costs, and its rationalization can bring great business and competitive advantages [4]. Effective distribution logistics occurs when using suitable modern technologies of automatic identification [5]. Typical automatic identification technologies used in distribution logistics are Bar codes, Quick Response codes (hereinafter QR codes), Radio Frequency Identification (hereinafter RFID) [5]. RFID technology has been used in a wide range of applications since the

1950s. Nowadays, RFID is beginning to develop and be used extensively in a variety of industries, especially where speed and accuracy of information is emphasized and then transmitted by corporate software for further reporting [6]. RFID uses information carriers, so-called tags, readers, and software to process information [7]. The big advantage of RFID is that there is no need for direct visual contact to retrieve tag information [7]. Accuracy with RFID means that due to the appropriate layout of the readers (antennas), the movements of packages, devices or employees can be monitored with great precision [6]. Thanks to this, many companies use RFID, for example in goods handling warehouses [6].

The role of warehousing stems from market needs and product shifting to the consumer and the basic types of stocks can be distinguished whether they are the supply stage or the distribution stage [8]. Warehousing provides both space and time benefits, helping to ensure a high level of customer service [8]. Resource planning as well as proper distribution logistics are critical steps in managing complex logistic networks [9]. Distribution centers, as important nodes, perform processes such as cargo concentration, processing, and distribution, with the support of equipment such as handling equipment [10]. All places where manipulation with customer's goods takes place e.g., from the vehicle to the warehouse and back or inside the warehouse are risk points, because provider of transportation services must ensure that all technological and physical processes are properly described and communicated to the customer and the customer must be informed about any deviation from previous processes [11]. Most researchers in China and overseas have studied the location of competing distribution centers from the largest market share gained by new distribution centers [12]. It was analyzed ways to make effective decisions about the location of new distribution centers so that they could gain the largest market share given the existing multiple distribution centers [12].

In today's globalization, logistics has become one of the value-added generators for the customers. Deconcentrating of demand and supply, increasing customer's demands lead to increased logistic costs [13]. It leads to a decrease in the sales margin or an increase in prices. It is therefore necessary to improve logistic processes [13]. Logistic processes often have considerable uncertainty associated with their complexity, the reliability of available information on current risks, and the availability of various statistical parameters from the previous period [14]. Today, many business-modelling tools are available to assist in analyzing and identifying logistic processes [15]. Simulation modelling techniques are one of the basic tools used to identify, analyses and optimize logistic processes and systems [15]. Nowadays, simulation tools can replace experiments, design, and improve systems, train and learn operators [16]. All measures are designed to operate in an environmentally friendly and cost-effective way [16]. Simulation offers many potential solutions and allows iteration of a previously developed model. This can help optimize all logistic processes [17]. Simulation models are important for the planning, implementation, and operation of logistic systems because they can display their dynamic system behavior [18]. Computer simulation is a well-accepted tool for modelling the behavior of large or complex operational logistic systems [19].

The aim of the paper is to find out what time savings the implementation of radio frequency identification technology can bring compared to barcode technology in the process of shipment consolidation.

2. METHODS

Experimental measurements are used in terms of scientific methods in a specialized Laboratory of Automatic identification which is located at the Faculty of Transport Engineering of the University of Pardubice. These measurements focused on the inspection of picked shipments prior to distribution within the process of shipment consolidation. The aim of measurements was to compare the use of automatic identification technologies (RFID and bar codes) in shipment consolidation process in terms of the time saving parameter. Pallet with shipments is shown in Figure 1. Each shipment was tagged with one UHF RFID tag and one 1D or 2D code.

Figure 1 Manipulation unit – pallet with shipments [authors]

The following equipment was used during the experimental measurements: Mobile (1D and 2D code) reader CIPHERLAB CP30 and Mobile RFID reader ZEBRA MC3390R (**Figure 2**).

Figure 2 Mobile (1D and 2D code) reader CIPHERLAB CP30 (on the left) and Mobile RFID reader ZEBRA MC3390R (on the right) [authors]

The first part of the experiment was devoted to the reading of shipments using mobile reader CIPHERLAB CP30 in the consolidation process. Shipments were labelled with the code GS-1 128 or GS1 QR Code (**Figure 3**). Thirty measurements were taken by three independent researchers and the time to read all shipments was measured. The second part of the experiment differed only in that the mobile RFID reader was used to read the shipments. Each shipment was tagged with UHF RFID tag (Confidex Steelwave Micro IITM, Confidex Casey SlimTM, Confidex Carrier MicroTM, Confidex Carrier Tough II™ and ALN-9662). **Figure 3** shows the selected different types of used UHF RFID tag.

Figure 3 Code GS1-128 (on the left), GS1 QR Code (in the middle), selected UHF RFID tags (on the right) [20,21, authors]

A schematic representation of the sub-processes within the two different types of experimental measurements of the inspection of picked shipments prior to distribution within the process of shipment consolidation process is shown in **Figure 4**. The main difference in the two analyzed automatic identification technologies is that in the case of barcode and QR code technology, it is necessary to read each inspected shipment individually

(upper process in the Figure 4). On the other hand, this is not necessary with RFID technology, as all shipments are scanned at once at the same moment (bottom process in the **Figure 4**).

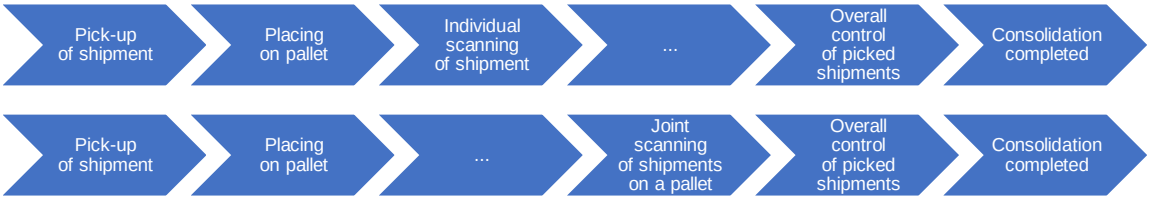

Figure 4 Sub-processes within the two different types of experimental measurements (barcode and QR code technology – upper process, RFID technology – bottom process) [authors]

Subsequently, a dynamic simulation method was used in the software Witness Horizon (version 22.5b) to determine the time savings in the duration of the shipment consolidation process using RFID technology compared to barcode and QR code technology. In recent years, many companies have started to use dynamic simulation to optimize business processes, as 3D visualization can facilitate the understanding of the links between processes, further contribute to process simplification and innovation, and indirectly save costs [22]. Computer simulation is one of the most effective approaches due to its ability and flexibility in simulating and evaluating static and dynamic systems, considering uncertainty and variability between systems [23]. Dynamic predictive simulation can be used in any logistics process, from warehousing and handling to production line optimization and distribution [24].

3. RESULTS

The average shipment pick-up time for both analyzed technologies was 1.60 s (minimum value), 2.25 s (mode value), 3.70 s (maximum value), and the average shipment placing on pallet time for both analyzed technologies was 0.80 s (minimum value), 1.90 s (mode value), 3.25 s (maximum value). The average scanning time of one shipment was 1.00 s (minimum value), 1.85 s (mode value), 2.50 s (maximum value) using mobile reader CIPHERLAB CP30. The average joint scanning time of shipments was 2.50 s (minimum value), 3.87 s (mode value), 5.00 s (maximum value) using mobile RFID reader ZEBRA MC3390R (**Table 1**).

Table 1 Input subprocess durations to dynamic simulation [authors]

Sub-process	**Barcode / QR code technology**			**RFID technology**		
	Min. [s]	Mode [s]	Max. [s]	Min. [s]	Mode [s]	Max. [s]
Pick-up of shipment	1.60	2.25	3.70	1.60	2.25	3.70
Placing on pallet	0.80	1.90	3.25	0.80	1.90	3.25
Individual scanning of shipment	1.00	1.85	2.50	---	---	---
Joint scanning of shipments on a pallet	---	---	---	2.50	3.87	5.00

The two analyzed scenarios (use of barcode / QR code technology and use of RFID technology) were then transformed into dynamic simulation software Witness Horizon and models were created. These models examined the duration of the consolidation process according to the number of shipments (**Figure 5**).

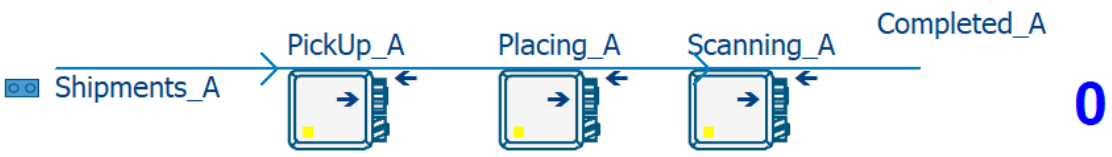

Figure 5 Visualization of the consolidation process in software Witness Horizon (version 22.5b) [authors]

The duration of the consolidation process was modelled for 50, 100, 150, ..., and 350 shipments for barcode / QR code technology and RFID technology (**Table 2**).

Table 2 Duration of the consolidation process according to technology and number of shipments [authors]

Number of shipments [-]	50	100	150	200	250	300	350
Barcode / QR code technology [s]	336	683	1 021	1 363	1 718	2 058	2 393
RFID technology [s]	262	517	757	1 007	1 267	1 527	1 792
Time saving for RFID technology [s]	-74	-166	-264	-356	-451	-531	-601

The analysis of both scenarios clearly shows the time savings of using RFID technology, which range from 22.02 to 26.25%. This time saving is mainly because when using RFID technology, it is possible to scan all shipments at once in a single moment, whereas with barcode/QR code technology it is necessary to scan each shipment individually.

4. CONCLUSION

The aim of the paper was to find out what time savings the implementation of radio frequency identification technology can bring compared to barcode technology in the process of shipment consolidation. Two types of experimental measurements were analyzed. Two types of experimental measurements were analyzed. The first focused on the use of barcode / QR code technology and the second focused on the use of RFID technology. The experimental measurements were carried out in the background of the Laboratory of Automatic identification. Based on the results of the experimental measurements, dynamic simulation models were created for each type of measurement in the software Witness Horizon. The Witness Horizon software modelled the duration of the consolidation process for different numbers of shipments.

The findings clearly demonstrate the time savings when using RFID technology compared to barcode or QR code technology. This time saving is mainly because it is possible to scan multiple shipments at the same time at the same moment. On the other hand, it must be stressed that RFID technology is more expensive to implement compared to barcode or QR code technology. The research contains the following limitations: only certain types of RFID tags, barcodes and QR codes were investigated. At the same time, only certain types of reading devices were used, while it is possible that other reading devices, tags and codes could give partially different results. Also, the results may be different for other types of shipments, in a different area where RFID technology may not work as well, or for other researchers who achieve different times in scanning shipments and other activities. Further research can be directed towards the use of other types of codes and RFID tags, as well as scanning devices or other logistic processes.

ACKNOWLEDGEMENTS

This article is published within the realization of the project "Cooperation in Applied Research between the University of Pardubice and Companies, in the Field of Positioning, Detection and Simulation Technology for Transport Systems (PosiTrans)", registration No.: CZ.02.1.01/0.0/0.0/17_049/0008394.

REFERENCES

[1] KUČERA, T., SUK, A. The application of ABC analysis in the logistic warehousing processes. In: *Transport Means: proceedings of the international scientific conference*. Kaunas: Kaunas University of Technology, 2019, pp. 548-554.

[2] GROS, I. *Velká kniha logistiky*. Praha: Vysoká škola chemicko-technologická v Praze, 2016.

[3] YANG, B., TONG, Y. Evolution dynamics modeling and simulation of logistics enterprise's core competence based on service innovation. In: *5th International Conference on Computer-Aided Design, Manufacturing, Modeling and Simulation (CDMMS)*. Busan: Amer Inst Physics, 2017.

[4] ZHANG, X., ZHANG, Y., WANG, Y. Study on logistics distribution simulation based on system dynamics. In: *2nd International Conference on E-Business and Information System Security (EBISS)*. Wuhan: IEEE, 2010.

[5] GS1. *EAN-13*. [online]. 2019. [viewed: 2022-05-02]. Available from: https://www.gs1cz.org/standardy-gs1/sber-dat/linearni-carove-kody/ean-13

[6] KONG, S., ZHAO, J., SHI, G., WU, CH., ZHAO, W., LIU, T. The Design and Implementation of the Attendance Management System based on Radio Frequency Identification Technology. In: *Proceedings of the 2015 International Conference on Electronic Science and Automation Control*. Paris: Atlantis Press, 2015, pp. 189-192.

[7] HUANG, CH., LV, Y. An Internet of Things System Based on Device-to-Device Communication Technology and Radio-Frequency Identification. *International Journal of Online Engineering*. 2018, vol. 14, pp. 210-218.

[8] KUČERA, T. Calculation of personnel logistics costs of warehousing. In: *Transport Means: proceedings of the international scientific conference*. Kaunas: Kaunas University of Technology, 2020, pp. 44-48.

[9] MOSCA, R., BRUZZONE, A., ORSONI, A. Integrated resource scheduling and simulation for dynamic logistic management. In: *17th European Simulation Multiconference*. Nottingham: SCS Europe, 2003, pp. 491-495.

[10] LIAO, H., QIN, R., WU, D., YAZDANI, M., ZAVADSKAS, E. K. Pythagorean Fuzzy Combined Compromise Solution Method Integrating the Cumulative Prospect Theory and Combined Weights for Cold Chain Logistics Distribution Center Selection. *International Journal of Intelligent Systems*. 2020, vol. 35, pp. 2009-2031.

[11] CEMPÍREK, V., NACHTIGALL, P., ŠIROKÝ, J. Security in Logistics. *Open Engineering*. 2016, vol. 6, pp. 637-641.

[12] SUN, H.J., GAO, Z.Y. Competitive Location Model of Logistics Distribution Center. *Journal of Traffic and Transportation Engineering*. 2002, vol. 2, pp. 54-57.

[13] ADAMCZAK, M., DOMANSKI, R., CYPLIK, P., SZYMANSKA, O. Delivering skills of simulation of logistic processes. *Acta Technica Napocensis Series – Applied Mathematics Mechanics and Engineering.* 2018, vol. 61, pp. 415-422.

[14] GAJOVIC, V., KERKEZ, M., KOCOVIC, J. Modeling and simulation of logistic processes: risk assessment with a fuzzy logic technique. *Simulation-Transactions of the Society for Modeling and Simulation International*. 2018, vol. 94, pp. 507-518.

[15] KARKULA, M., BUKOWSKI, L. Computational methods-joint use in discrete event model of logistics processes. In: *Winter Simulation Conference Proceedings*. Berlin: IEEE, 2012.

[16] KORNER, H.J., SCHWARZE-BENNING, K., DEERBERG, G. Simulation-based system for integration of logistic and process engineering decision processes. *Chemie Ingenieur Technik*. 2004, vol. 76, pp. 1476-1480.

[17] BANAS, J. Modeling and simulation of processes in logistics. Knowledge, practical skills and expectations in teaching of students. In: *INTED 2017: 11th international technology, education and development conference*. Valencia: IATED-INT, 2017, pp. 6753-6762.

[18] REGGELIN, T., TOLUJEW, J. A mesoscopic approach to modeling and simulation of logistics processes. In: *Proceedings of the 2011 winter simulation conference*. Phoenix: IEEE, 2011, pp. 1508-1518.

[19] OLSSON, B., BODON, P., GLASSOCK, C., ELIAS, M. Use of dynamic simulation as an optimisation and risk management tool in process and logistics operations. In: *Mining risk management conference*. Sydney: Australasian Inst Mining & Metallurgy, 2003, pp. 277-282.

[20] GS1. *GS1-128*. [online]. 2020. [viewed: 2022-05-17]. Available from: https://www.gs1cz.org/standardy-gs1/sber-dat/linearni-carove-kody/gs1-128

[21] GS1. *GS1 QR Code*. [online]. 2020. [viewed: 2022-05-18]. Available from: https://www.gs1cz.org/standardy-gs1/sber-dat/2d-kody/gs1-qr-code

[22] TVRDOŇ, L., FEDORKO, G. Usage of dynamic simulation in pressing shop production system design. *International Journal of Simulation Modelling*. 2020, vol. 19, pp. 185-196.

[23] ZAHRAEE, S.M., ROHANI, J.M., FIROUZI, A., SHAHPANAH, A. Efficiency improvement of blood supply chain system using taguchi method and dynamic simulation. *Procedia Manufacturing*. 2015, vol. 2, pp. 1-5.

[24] SCHINDLEROVÁ, V., ŠAJDLEROVÁ, I. Use of the Dynamic Simulation to Reduce Handling Complexity in the Manufacturing Process. *Advances in Science and Technology Research Journal*. 2020, vol. 14, pp. 81-88.