Proceedings of 25th International Scientific Conference. Transport Means 2021.

Use of RFID Technology in the Logistic Process of Distribution with the Support of a Dynamic Simulation Software Tool

R. Hruška[1], J. Chocholáč[2], T. Kučera[3]

[1] *University of Pardubice, Faculty of Transport Engineering, Studentská 95, 532 10, Pardubice, Czech Republic, E-mail:* roman.hruska@upce.cz
[2] *University of Pardubice, Faculty of Transport Engineering, Studentská 95, 532 10, Pardubice, Czech Republic, E-mail:* jan.chocholac@upce.cz
[3] *University of Pardubice, Faculty of Transport Engineering, Studentská 95, 532 10, Pardubice, Czech Republic, E-mail:* tomas.kucera@upce.cz

Abstract

In recent years, the volume of parcels sold electronically has increased significantly. The current pandemic period has amplified this, as the volume of e-shop transactions has grown even more. Due to the COVID-19 pandemic and related restrictive measures, most stone shops are closed in the Czech Republic. Customers most often use e-shops to buy goods. As a result, the volume of parcel transport, which is provided by parcel carriers, is increasing to finish customers. Improving distribution logistics and the entire logistic system are constantly under pressure in the context of existing competition, maintaining the declared level of customer service and increasing volume of parcels. One way to streamline the logistic distribution process is to use RFID technology as one of the automatic identification technologies. The aim of the article is to create the proposal for the use of RFID technology in the distribution process of parcels in order to make it more effective. Simulation software the Witness Horizon will used to achieve the aim. The software uses the dynamic simulation to evaluate the benefits of using RFID technology before its implementation.

KEY WORDS: *logistic process, distribution, distribution centre, dynamic simulation, parcel, RFID technology*

1. Introduction

With the development of the economy, the logistic industry, as an ancillary industry, has developed very rapidly and its level of service has been constantly improving, but the high cost of logistics is still a matter of great concern. Logistic distribution costs make up a large part of the total logistic costs. If the journey can be reasonably planned and optimized to reduce time and distribution costs, logistic costs can be reduced. A number of basic capabilities of logistic companies between mutual influence and mutual support, overall increase of basic capabilities of logistic companies. The basic skills of logistic companies are constantly improving.

Logistic companies generally do not have key competitiveness, there is a lack of awareness of service innovation about the problems to be solved, and dynamic research methods should be used to study the key competencies of a company to study the key competencies of logistic companies. The development of the basic competence of logistic companies is a process of dynamic change. The aim of the article is to create the proposal for the use of RFID (Radio Frequency Identification) technology in the distribution process of parcels in order to make it more effective. Simulation software the Witness Horizon will used to achieve the aim of the article.

2. Theoretical Background

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. Typical managed activities include transportation, fleet management, warehousing, material handling, order fulfilment, logistic network design, inventory management, supply and demand planning, and logistic service provider management especially in distribution part of logistics. To varying degrees, logistic functions also include sourcing and purchasing, production planning and scheduling, packaging and assembly, and customer service. It is involved in all levels of planning and implementation - strategic, operational and tactical. 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 [1]. Distribution centres, as important nodes, perform processes such as cargo concentration, processing and distribution, with the support of equipment such as handling equipment [2]. The selection of logistic distribution centres is a problem that includes qualitative and quantitative criteria [3-4]. In order to better meet the distribution needs of companies, economic efficiency and customer satisfaction are increasing and the number of logistic distribution centres is increasing from year to year [5-6].

Most researchers in China and overseas have studied the location of competing distribution centres from the largest market share gained by new distribution centres [7]. It was analysed ways to make effective decisions about the location of new distribution centres so that they could gain the largest market share given the existing multiple distribution centres [8]. Other scholars proposed a mathematical model for selecting a competitive logistic distribution centre, taking maximum market share as their objective task to achieve the best profit [9].

Pandemics and epidemics are far-reaching threat scenarios that are increasing in frequency [10]. The resulting crises can have serious consequences, especially from a medical, social and economic point of view, as demonstrated by the COVID-19 pandemic in 2020. In pandemics, measures such as reducing social interaction and self-isolation are aimed at managing the disease and mitigating negative impacts [11]. Because grocery stores are places of close personal contact, they can cause infections. Visits should be limited while following public isolation recommendations [12-13]. However, the supply of basic goods, especially food, to the population must be maintained at all times. Home delivery is a logistic solution that reduces social interactions and is therefore suitable for pandemic conditions [14-15]. Disruptions in the logistic chain can jeopardize supply [16]. Last-mile relief logistics is the last stage in aid supply chains and aims to distribute goods to people with disabilities [17]. Other authors emphasize the importance of limited transport resources for emergency delivery in last mile logistics [18]. Distribution costs form a large part of the final selling price of the product and consist of both fixed and variable costs. Therefore, companies must reduce one or both of these costs in order to achieve higher demand for products from customers. Fixed costs come mainly from the driver's salary or the cost of using the vehicle and burden the distribution company by the mere use of the vehicle, regardless of the route and the number of customers served [19].

As the importance of innovation in logistic businesses becomes increasingly important, companies continue to help improve user relationships, improve operational efficiency and reduce logistic costs [20-22]. The ability to innovate services has therefore become one of the most important parts of the core competencies of logistic companies. The phase of forming the basic competence of logistic companies, the basic competence of the modernization phase and the main competence of modernization [23].

The operation of the model simulation consists mainly in testing the accuracy and validity of the results of the model simulation and the validity is mainly testing whether the information obtained by the model can objectively reflect the operating rules of the real system and whether problems can be solved after studying the model. Test methods include model structure and validity detection, model structure behaviour, and real system consistency detection [24].

3. Methods

The following scientific methods were used to create the proposal for the use of RFID technology in the distribution process of parcels in order to make it more effective within this article: scenario analysis, experimental testing of barcodes and RFID technology and dynamic simulation.

The scenario analysis is based on formulated alternatives when probabilities of uncertainties are un-known and can be used to integrate uncertainties into the performance robustness assessment [25-27]. Scenarios are used to present a range of possible alternatives so that the performance robustness of designs can be assessed based on how different designs perform in each of these alternatives [28]. Authors analysed, simulated and tested two scenarios (scenario A and B) related to the logistic process of parcels distribution. Both scenarios simulate the final phase of distribution of parcels from the distribution centre. Parcels are prepared in the dispatch zone and must be registered in the internal information system and handed over to the driver for loading into a truck. In both scenarios, there are two workers (picker and driver).

The crucial difference between the scenarios is from a technological perspective because the picker in scenario A uses barcodes technology, specifically handheld mobile terminal and barcodes reader CipherLab CP30 WM 6.5 Pro and EAN-13 barcodes. After loading the parcel into the information system, the parcel is then handed over to the driver for loading. In scenario B, the picker uses a belt conveyor to deliver parcels to the driver and RFID technology (specifically fix reader Motorola FX9500, RFID dual antenna AN440, notebook including SessionOne software for device discovery, inventory operations, access operations, export tags, tags Alien ALN-9613 Sit Inlay and connecting cables) to ensure that parcels are loaded into the internal information system. The experimental testing of barcodes and RFID technology was provided in a specialized Laboratory of Automatic Identification of the Faculty of Transport Engineering, University of Pardubice. As part of this testing, the average durations of individual processes within the parcels distribution process were experimentally measured using RFID technology and barcode technology. The visualization of the RFID technology experimental testing is presented in Figure 1.

Fig. 1 The visualization of the RFID technology experimental testing [authors]

The logistic process of parcels distribution was analysed, simulated and tested using the specialized software for dynamic simulation (Witness Horizon, version 22.5b). In recent years, many companies have begun to use dynamic simulation to optimize business processes, as it can make it easier to understand the relationships between processes, help simplify and innovate processes, and indirectly save costs [29]. The use of dynamic simulation in the field of logistics has been very popular in recent years, for example in the area of: demand planning in the supply chain [30], optimization of production lines [31], modelling of city logistics [32], optimization of production logistics [33], and supply chain management [34]. The dynamic predictive simulation can be used in any logistic process, from warehousing and handling through optimization of production lines to distribution [29]. For the correctly generalized simulation results there have to be multiple tests, and multiple possible scenarios have to be examined [35]. Firstly, models were created for both scenarios using Witness Horizon. The models were subsequently verified and validated. Then the individual scenarios were tested and evaluated. The models were calibrated for the distribution of 50, 100, 150, 200, 250, 300, 350, 400, 450 and 500 parcels. The durations of the individual sub-processes included in the models were defined on the basis of experimental testing and measuring in a specialized Laboratory of Automatic Identification. The duration of the sub-processes is assumed to the triangular probability distribution with parameters *a* (minimum duration [s]), *b* (average duration [s]), *c* (maximum duration [s]). The overview of the duration of the individual sub-processes is in Table 1.

Table 1 The duration of the sub-processes within the simulated distribution process [authors]

Scenario	Picker			Driver		
	a [s]	b [s]	c [s]	a [s]	b [s]	c [s]
A	30	45	60	30	40	50
B	20	30	40	25	35	45

The main monitored parameter was the total duration of the distribution process for the both scenarios and 50, 100, 150, 200, 250, 300, 350, 400, 450 and 500 parcels. Both scenarios assume flawless functionality of the simulated and tested technologies.

4. Results and Discussion

Firstly, models of both scenarios were created in the Witness Horizon software for dynamic simulation. An example of both created models is presented in Figure 2. Scenario A model is based on the use of barcodes technology in the parcels distribution process. Scenario B model is based on the use of RFID technology and a belt conveyor in the parcels distribution process. The durations of the sub-processes correspond to the values in Table 1.

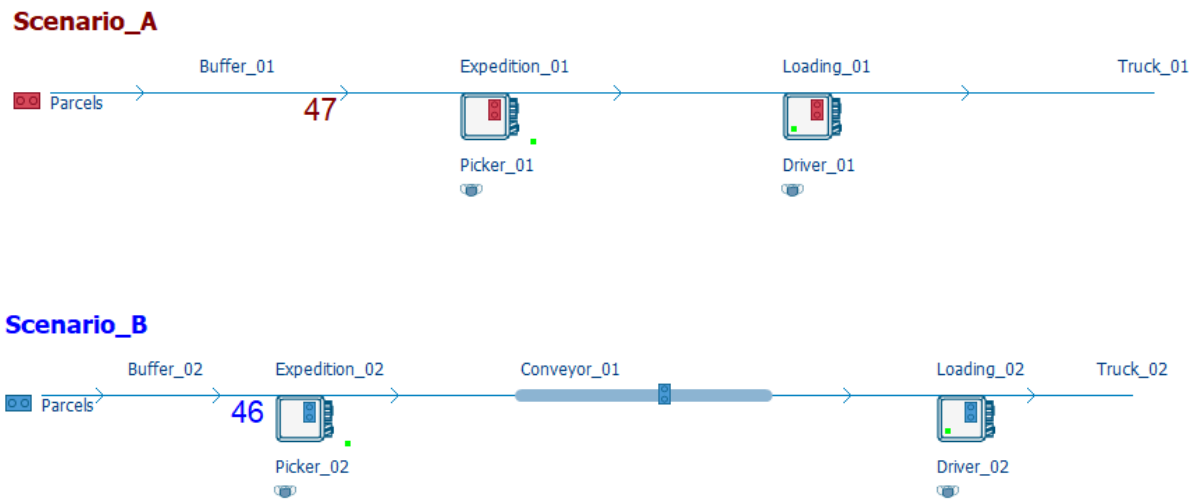

Fig. 2 Created models for both scenarios [authors, Witness Horizon]

The models were subsequently verified and validated. Then the individual scenarios were tested and evaluated for the distribution of 50, 100, 150, 200, 250, 300, 350, 400, 450 and 500 parcels from the perspective of the main monitored parameter (the total duration of the distribution process). The results of the main monitored parameter of both scenarios for different parcels volumes are presented in Figure 3.

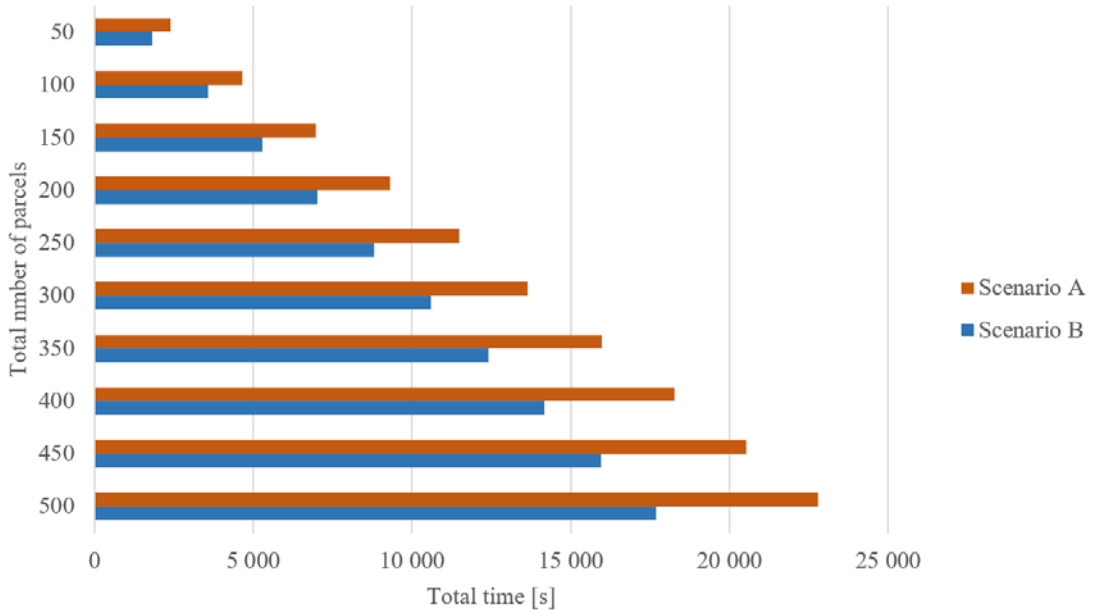

Fig. 3 Comparison of the total duration of the parcels distribution process (scenario A and B) [authors]

The total duration of the distribution process for 50 parcels was based on a dynamic simulation results for scenario A 2 386 s (40 minutes after rounding) and for scenario B 1 823 s (31 minutes after rounding). The total duration of the parcels distribution process in scenario B is shorter by 9 minutes, so the time saving is 23.6 %. The situation is very similar for other tested numbers of parcels, for example for 300 parcels was based on a dynamic simulation results for scenario A 13 652 s (3 hours and 48 minutes after rounding) and for scenario B 10 604 s (2 hours and 57 minutes after rounding). The total duration of the parcels distribution process in scenario B is shorter by 51 minutes, so the time saving is 22.3 %, and for 500 parcels was based on a dynamic simulation results for scenario A 22 797 s (6 hours and 20 minutes after rounding) and for scenario B 17 696 s (4 hours and 55 minutes after rounding). The total duration of the parcels distribution process in scenario B is shorter by 1 hour and 25 minutes, so the time saving is 22.4 %.

The results clearly show that the total duration of the parcels distribution process in scenario A is significantly longer for all simulated parcels amounts than in scenario B. This finding implies the conclusion that the use of RFID technology in the distribution process shortens the duration of this process compared to the use of barcodes technology. The use of RFID technology resulted in a time saving of 22.2 to 24.5 % in individual tests. This study also contains many limitations. The first limit is the technical and technological equipment used because there are other barcode readers,

other types of barcodes, RFID tags, RFID readers and RFID antennas on the market. Another limitation may be the fact that RFID technology may not work flawlessly in every environment. This requires further testing and debugging. The last limit is the fact that the study assumes flawless functionality of the simulated and tested technologies.

5. Conclusion

The simulation of the distribution process is the excellent tool for the data analysis, which takes place in almost every parcel carrier. The aim of the article was to create the proposal for the use of RFID technology in the distribution process of parcels in order to make it more effective within this article: scenario analysis, experimental testing of barcodes and RFID technology and dynamic simulation. The conclusion that the use of RFID technology in the distribution process streamlines the duration of this process compared to the use of barcodes technology. Witness Horizon software is the important tool to support logistic planning and optimization of logistic processes because dynamic simulation enables to virtually streamline processes before their implementation in practice.

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. **Gros, I.** 2016. Velká kniha logistiky. Praha: Vysoká škola chemicko-technologická v Praze, 507 p. (in Czech).
2. **Liao, H.; Qin, R.; Wu, D.; Yazdani, M.; Zavadskas, E. K.** 2020. 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 35(12): 2009-2031.
3. **Cheng, M. Y.; Tsai, H. C.; Chuang, K. H.** 2011. Supporting International Entry Decisions for Construction Firms Using Fuzzy Preference Relations and Cumulative Prospect Theory, Expert Systems with Applications 38(12): 15151-15158.
4. **Curkovic, S.; Melnyk, S. A.; Handfield, R. B.; Calantone, R.** 2000. Investigating the Linkage between Total Quality Management and Environmentally Responsible Manufacturing, IEEE Transactions on Engineering Management 47(4): 444-464.
5. **Zhao, J.; Xiang, H.; Li, J.; Liu, J.; Guo, L.** 2020. Research on Logistics Distribution Route Based on Multi-objective Sorting Genetic Algorithm, International Journal on Artificial Intelligence Tools 29(7-8): Special Issue.
6. **Wang, S. W.; Yang, F.; Xu, L.** 2019. Discrete Differential Evolution Algorithm for Shared Bicycle Scheduling Problem, Journal of Zhengzhou University 23(4): 325-336.
7. **Zhang, S.; Chen, N.; She, N.; Li, K.** 2021. Location Optimization of a Competitive Distribution Center for Urban Cold Chain Logistics in Terms of Low-carbon Emissions, Computers & Industrial Engineering 154: 1-13.
8. **Sun, H. J.; Gao, Z. Y.** 2002. Competitive Location Model of Logistics Distribution Center, Journal of Traffic and Transportation Engineering 2(4): 54-57.
9. **Gao, H.; Xu, G. H.; Wang, Z. R.; Yang, H.** 2007. Application of Clonal Selection Algorithm on Competitive Location Model of Logistics Distribution Center, Journal of Highway and Transportation Research and Development 24(6): 144-148.
10. **Nandy, A.; Basak, S.** 2017. Viral Epidemics and Vaccine Preparedness, Journal of Molecular Pathological Epidemiology 2(1): 1-5.
11. **Breitbarth, E.; Gross, W.; Zienau, A.** 2021. Protecting Vulnerable People during Pandemics through Home Delivery of Essential Supplies: A Distribution Logistics Model, Journal of Humanitarian Logistics and Supply Chain Management 1-21.
12. **Ekici, A.; Keskinocak, P.; Swann, J. L.** 2013. Modeling Influenza Pandemic and Planning Food Distribution, Manufacturing and Service Operations Management 16(1): 11-27.
13. **Haug, A.; Brand-Miller, J.; Christophersen, O.; Mcarthur, J.; Fayet-Moore, F.; Truswell, A.** 2007. A Food Lifeboat: Food and Nutrition Considerations in the Event of a Pandemic or Other Catastrophe, The Medical Journal of Australia 187: 674-6.
14. **Ekici, A.; Keskinocak, P.; Swann, J. L.** 2013. Modeling Influenza Pandemic and Planning Food Distribution, Manufacturing and Service Operations Management 16(1): 11-27.
15. **Haug, A.; Brand-Miller, J.; Christophersen, O.; McArthur, J.; Fayet-Moore, F.; Truswell, A.** 2007. A Food Lifeboat: Food and Nutrition Considerations in the Event of a Pandemic or Other Catastrophe, The Medical Journal of Australia 187: 674-6.
16. **Dalton, C. B.** 2006. Business Continuity Management and Pandemic Influenza, New South Wales Public Health Bulletin 17(10): 138-141.
17. **Balcik, B.; Beamon, B.; Smilowitz, K.** 2008. Last Mile Distribution in Humanitarian Relief, Journal of Intelligent Transportation Systems 12(2): 51-63.

18. **Maghfiroh, M. F. N.; Hanaoka, S.** 2018. Dynamic Truck and Trailer Routing Problem for Last Mile Distribution in Disaster Response, Journal of Humanitarian Logistics and Supply Chain Management 8(2): 252-278.
19. **Konstantakopoulos, G. D.; Gayialis, S. P.; Kechagias, E. P.** 2020. Vehicle Routing Problem and Related Algorithms for Logistics Distribution: A Literature Review and Classification, Operational Research.
20. **Chen, Y. F.** 2012. To Build a Customer to Participate in the Bridge to Drive the Logistics Service Innovation, Logistics Technology 34(8).
21. **Du, J.** 2012. Analysis on the Driving Force of Logistics Service Innovation and its Influencing Factors, Economic Research Guide 30(20).
22. **Yang, B.; Tong, Y.** 2017. Evolution Dynamics Modeling and Simulation of Logistics Enterprise's Core Competence Based on Service Innovation, 5th International Conference on Computer-Aided Design, Manufacturing, Modeling and Simulation 1834: 1-11.
23. **He, L.; Ding, H. P.** 2009. Research on the Formation and Evolution Mechanism of Enterprise Capability based on Value Creation: A Case Study of Express Logistics Enterprises, Business Management 24(5).
24. **Wang, W.; Yin, H.; Tang, Y.; Xu.** 1993. A Methodology for Validation of System and Sub-system Level Models, Department of System Engineering and Mathematics, National University of Defence Technology.
25. **Hopfe, C.J.; Augenbroe, G.L.M.; Hensen, J.L.M.** 2013. Multi-criteria decision making under uncertainty in building performance assessment, Building and Environment 69: 81-90.
26. **Struck, C.; Hensen, J.L.M.** 2013. Scenario analysis for the robustness assessment of building design alternatives – a dutch case study, Cleantech for smart cities & buildings from nana to urban scale: 939-944.
27. **Kim, S.H.** 2013. An evaluation of robust controls for passive building thermal mass and mechanical thermal energy storage under uncertainty, Applied Energy 111: 602-623.
28. **Polasky, S.; Carpenter, S.R.; Folke, C.; Keeler, B.** 2011. Decision-making under great un-certainty: Environmental management in an era of global change, Trends in Ecology & Evolution 26: 398-404.
29. **Schindlerova, V.; Sajdlerova, I.** 2020. Use of the Dynamic Simulation to Reduce Handling Complexity in the Manufacturing Process, Advances in Science and Technology Research Journal: 14(1), 81-88.
30. **Ashayeri, J.; Lemmes, L.** 2006. Economic value added of supply chain demand planning: A system dynamics simulation, Robotics and Computer-Integrated Manufacturing 22(5-6): 550-556.
31. **Hatami, M.; Zahraee, S.M.; Khademi, A.; Shahpanah, A.; Rohani, J.M.** 2014. Evaluating the effect of main factors in manufacturing production line based on simulation experiment, Applied Mechanics and Materials 606: 199-203.
32. **Firdausiyah, N.; Taniguchi, E.; Qureshi, A.G.** 2019. Modeling city logistics using adaptive dynamic programming based multi-agent simulation, Transportation Research Part E 125: 74-96.
33. **Tvrdoň, L.; Fedorko, G.** 2020. Usage of dynamic simulation in pressing shop production system design, International Journal of Simulation Modelling 19(2): 185-196.
34. **Golroudbary, S.R.; Zahraee, S.M.** 2015. System dynamics model for optimizing the recycling and collection of waste material in a closed-loop supply chain, Simulation modelling practice and theory 53: 88-102.
35. **Tischer, E.; Nachtigall, P.; Siroky, J.** 2020. The use of simulation modelling for determining the capacity of railway lines in the Czech conditions, Open Engineering 10(1): 224-231.