ORDER PICKING SYSTEM ANALYSIS FOR E-COMMERCE ENTERPISE ON THE BASIS OF SIMULATION MODEL

Alicja DĄBROWSKA, Robert GIEL, Marcin PLEWA

Wroclaw University of Science and Technology, Wroclaw, Poland, EU
alicja.dabrowska@pwr.edu.pl, robert.giel@pwr.edu.pl, marcin.plewa@pwr.edu.pl

Abstract

Popularization of Internet access and socio-economic growth were the reasons of taking the 13th place by Poland in the list of countries according to the speed of e-commerce market development. The dynamics of this development determines the need to constantly analyze processes in e-commerce enterprises and make changes to meet the growing demands of customers. Short delivery time is now a key factor, which significantly affects gaining competitive advantage. One of the increasingly used solutions allowing to get it, is implementing goods to person principle in the picking process.

Using this principle is connected with the necessity of applying conveyors, stacker cranes and/or automated guided vehicles. Implementing this kind of handling equipment creates the need of system analysis already at the design stage. To make this possible without interfering with the real system, simulation modeling is used increasingly often. Representation of considered system operation with the use of simulation methods is not only a good supporting tool in designing new system elements. It can also be used to analyze warehouse solutions, which have been already implemented.

Simulation model of picking process with the use of conveyors and stacker cranes was used in this article. The model was subjected to sensitivity analysis to indicate its problematic areas, to determine its maximum efficiency and factors which can negatively influence on its reliability. Maximum frequency of releases from the storage area and efficiency of picking and packing stations were also presented.

Keywords: E-commerce, simulation modeling, logistics, picking, goods to person

INTRODUCTION

The number of Internet users in Poland maintains an upward trend over the years. Currently, their number is estimated at 27.5 million people, which is more than 71 % of the polish population, what shows Geminus' report *E-commerce in Poland 2019*. In addition, there has been a noticeable increased interest in online shopping in recent years. In connection with the above, the e-commerce market is dynamically developing in Poland. This is confirmed by the growing share of the value of this market in Poland's GDP every year (**Figure 1**). In 2018 e-commerce market had the value of over 18 billion euro.

In the context of e-commerce, the authors present its current state and development prospects, based on publicly available reports. The number of online stores over the years and their distribution based on activity time on market and number of employees is presented. The age of the clients, the type of products most frequently bought and the opinions of Internet users about online shopping are also taken into account. In addition, problematic areas are indicated along with proposals for their improvement [2], as well as barriers to the development of e-commerce enterprises [3].

Growing number of online stores is the reason for greater choice of products, but it is also connected with setting greater expectations by clients. Low prices, high quality and wide range of offered products is currently not enough. Key factor, which can provide new clients and keep the regular ones is a guarantee of short delivery time. In connection to this, e-commerce enterprises are aiming to shorten warehouse processes [4-7], which are constantly analyzed and evaluated [8-10]. Technological solutions limiting human participation in the preparation of orders to a minimum in order to apply partial or complete process automation are implemented. The use of automated guided vehicles [11-13], stacker cranes, automatic shelving [14-17] and conveyor system [18-20] is becoming more and more common. The process where these solutions are used is primarily the picking process [21-23]. Picking can be done by two main principles: person to goods or goods to person. In the first one picker moves to given locations from the picking list, where ordered products are located. Time of walking between locations is strictly connected with unpredictable human factors [24,25] and it is also over 50 % of the total picking process time [26]. According to this, more and more often goods to person principle is implemented. In this principle necessity of moving between locations is eliminated, which is very often a reason for not completing orders according to the set time. The application of this principle eliminates the need to implement route planning algorithms that are part of transport problems [27-31].

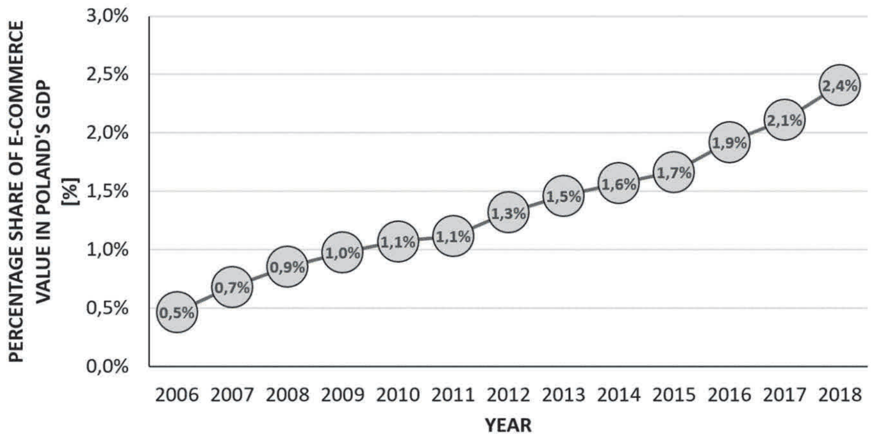

Figure 1 Share of e-commerce market value in Poland's GDP [1]

One of the solutions in goods to person principle is implementation of a system consisting of stacker cranes and conveyors. In this type of system picker's role is limited to picking the product and putting it in the right container. The picking system with type of solutions has been analyzed in this article.

The aim of this article is to present picking process analysis for the e-commerce enterprise on the basis of simulation model. Maximum frequency of releases from the storage area and efficiency of picking and packing stations were presented. Additionally, maximum efficiency of the system and its problematic areas were shown.

SYSTEM AND MODEL DESCRIPTION

In analyzed system two types of orders can be seen: for individual clients and for enterprises. They are distinguished by the type of packaging. Orders for individual clients are placed in cardboard boxes and orders for enterprises are placed in plastic containers.

The input in analyzed system are client's orders. The system can be divided into two subsystems (**Figure 2**):

- Subsystem of releases from the storage area, which are based on clients' orders (subsystem 1)
- Subsystem of picking and packing processes with the use of goods to person principle (subsystem 2)

The processes from subsystem 1 can be described in the following points:

1.1. Client makes order through the website.

1.2. The order is directed to the warehouse management system and queued as part of ongoing tasks

1.3. Location of order's components is searched and the product is reserved

1.4. Stacker crane takes the klt-box from the rack and transports it to the conveyor
1.5. Klt-box moves to one of six picking stations
1.6. After picking the right product by the picker, klt-box moves back to the stacker crane*
1.7. Stacker crane puts the klt-box to its location

*In the case when klt-box is empty, it is removed from the conveyor, refilled and placed back on the conveyor

The processes from subsystem 2 can be described in the following points:

1.1. In the picking station, on one from six monitors full information about order is showed
1.2. Picker prepares the appropriate packaging (depending on the client type) and puts it under the monitor. On the conveyor from subsystem 1 order's component is transported. After picking the right component from the klt-box, picker puts this box on another conveyor, which transports it to the stacker crane
1.3. The previous activity is carried out until picking process of given order is finished. After this picker pushes the container on another conveyor located behind picking points. Container is transported to the carton closing machine.
1.4. Containers are transported to the packing stations, where they are prepared for shipment. If the order was packed in plastic container, packer puts the new container on conveyor. If the order was packed in cardboard box, new box is sent from the cartoning machine.

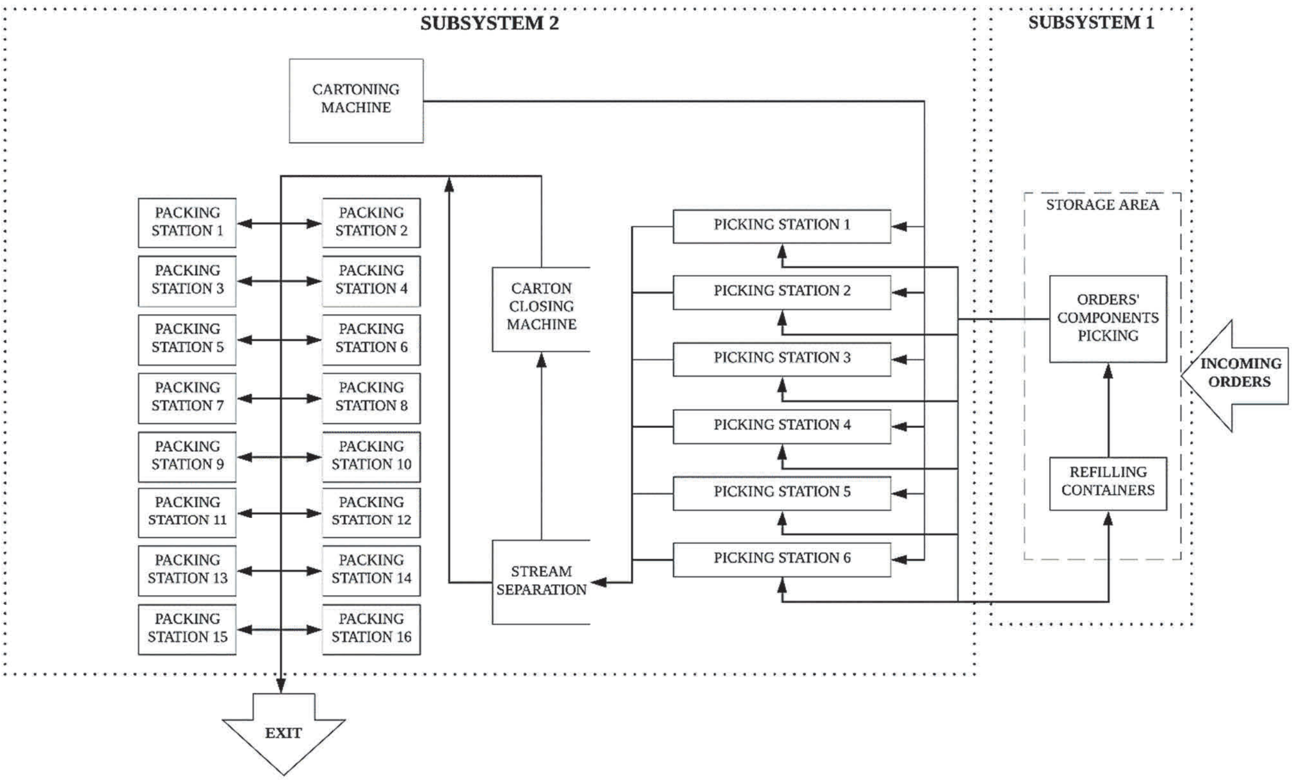

Figure 2 Scheme of the picking system

Modeling [32,33] and simulation are used to analyze processes in detail characterized by randomness [34-38]. Simulation model used in this article to analyze picking process was created with the use of Flexsim software. This model is characterized by constant and variable parameters (**Table 1**).

Table 1 Model's constant and variable parameters

Name of the parameter	Designation	Value
Constant		
Speed of the conveyor	V_c	1 m/s
Number of picking stations	n_{pa}	6 units
Number of packing stations	n_{pi}	16 units
Working hours per shift	t	8h
Variable		
Number of pickers	n_1	{1, …, 6}
Number of packers	n_2	{1, …, 10}
Frequency of releases from the warehouse	t_w	{0.8; 1; 2; 3; 3.34; 4; 5} s

The visualization of the picking system in the analyzed enterprise is shown on **Figure 3**.

Figure 3 Visualization of the analyzed picking system in Flexsim software

A sensitivity analysis was carried out to determine the maximum efficiency of the system and to identify its limitations. By changing the input parameters and conducting 100 repetitions of simulation, the number of orders finished in the picking process and packing process were examined.

RESULTS OF SIMULATION

In order to transport klt-boxes to the picking stations just in time, there must be correctly established frequency of releases from the storage area. Currently it is 3.34 seconds. By checking longer and shorter time intervals it was possible to designate the best fitted time. After conducting 100 hundred repetitions of simulations, results were presented in form of a chart (**Figure 4**).

Time interval longer than 3.34s gives worse results than the time currently used. However implementing 3 seconds as time interval can give better efficiency. It is possible to get 249 packed orders per 1 hour instead of 222 packed orders. Additionally, with this interval percent of packed orders in picked orders is the highest at the level of over 81 %.

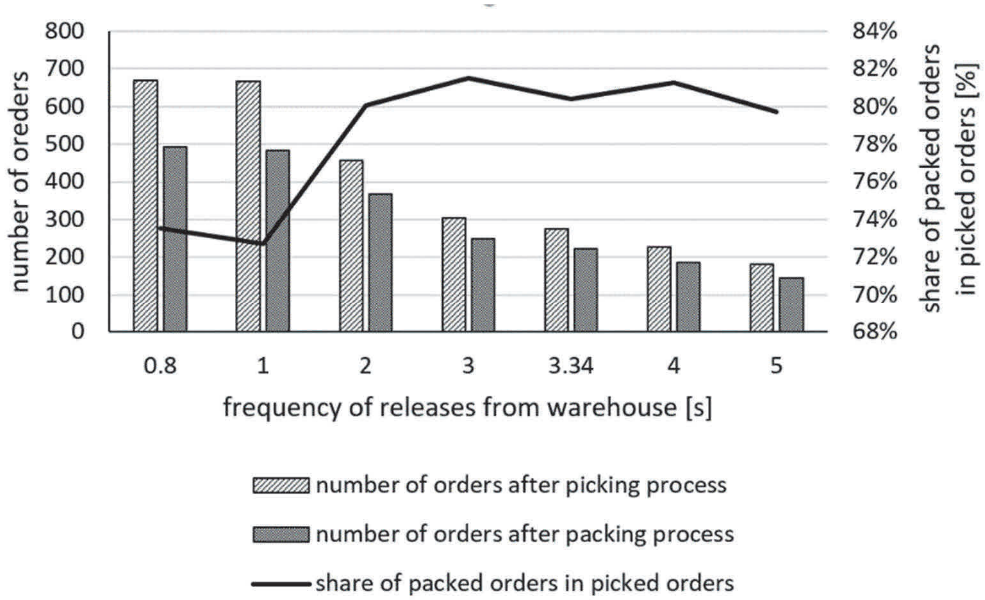

Figure 4 Number of orders finished in picking and packing process per 1 hour

Important parameters in analyzed system are also number of pickers and packers. Taking into account currently used frequency of releases from the storage area, number of required pickers and packers was examined. There are six available picking stations in the system. Results show that with the releases from warehouse every 3.34s, efficiency of picking stations with the use of 3, 4 or 5 pickers is at the similar level (**Figure 5**).

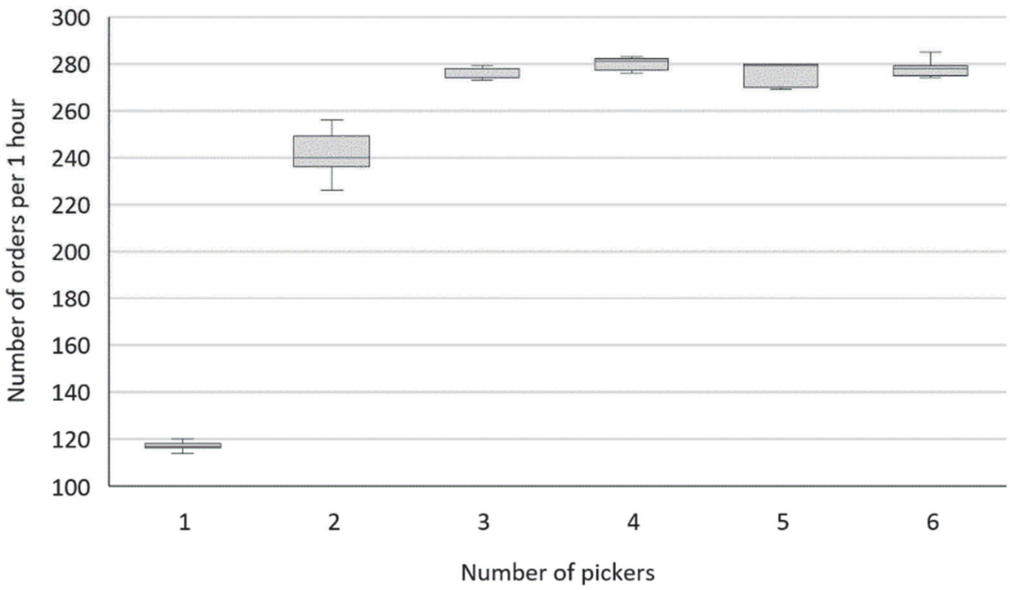

Figure 5 Efficiency of picking stations with the use of different number of pickers

Using 4 pickers instead of six can give the highest average efficiency of picking stations (280 orders per 1 hour) with results concentrated around it.

Correct number of pickers is not enough to get the best possible overall efficiency. As important as number of pickers is also proper number of packers. Number of packers was changed and number of packed orders was compared with the number of previously picked orders (**Figure 6**).

Figure 6 Efficiency of packing stations with the use of different number of packers

On the basis of results it can be stated that with 7 packers it is possible to get the highest number of packed orders per 1 hour. Getting better efficiency with less number of packers is connected with applied conveyors. More packers means longer transport path, which is the reason of lower efficiency. However too few packers can create situation, where conveyor is blocked because of orders are not packed on time.

CONCLUSION

Goods to person principle implemented in the picking process can largely eliminate unpredictable human factors, which are one the the main reasons of delayed order processing. Conveyor systems are solutions very often applied according to this principle. In analyzed e-commerce enterprise used conveyor system has serial structure. Every element of the system is strictly connected with the others. Due to this, occurrence of damage in any element can stop the entire system. This is the main limitation of such systems. With the use of Flexsim software, simulation model was created. Results of conducted simulations enabled to indicate the number of pickers and packers and also the time interval between releases from storage area, which can give the highest efficiency. Reducing number of pickers and packers can give improvement in picked and packed orders per 1 hour. In making changes in conveyor systems or implementing them, it is important to consider connections between elements. In choosing proper number of pickers, there should be number of packers and frequency of releases from warehouse taken into consideration. Too many or too few workers can lead to lower efficiency.

REFERENCES

[1] PMR Industry report: Online retail market in Poland 2018

[2] BREDZEL-SKOWERA, Katarzyna and TUREK, Tomasz. The Prospects of E-commerce in Poland. *Procedia Computer Science*. 2015. Vol. 65, pp. 1114-1123

[3] BRENDZEL-SKOWERA, Katarzyna, KOŚCIELNIAK, Helena, ŁUKASIK, Katarzyna and PUTO, Agnieszka. The conditions for development of e-commerce in Poland. Proceedings of International Academic Conferences. 2015, pp. 191-200. Available from: DOI: 10.20472/IAC.2015.015.035

[4] HABAZIN, Josip, GLASNOVIĆ, Antonia and BAJOR, Ivona. Order Picking Process in Warehouse: Case Study of Dairy Industry in Croatia. *Promet - Traffic - Traffico*. 2017. Vol. 29, no.1, pp. 57-65

[5] GERMAN, Josephine, ASUNCION, Maria Katrina and PACHECO, Louie. Increasing productivity and efficiency for third party logistics service. *Proceedings of the International Conference on Industrial Engineering and Operations Management, Bangkok, Thailand, March 5-7*, 2019

[6] SHOEB, Mohd. Implementation of lean principles to improve the operations of a sales warehouse in the manufacturing industry. *International Journal of Engineering Research and Application*. 2017. vol. 7, no. 6, pp.41-46

[7] PHUPATTARAKIT, Thanichkarn and CHUTIMA, Parames. Warehouse Management Improvement for a Textile Manufacturer. *IEEE 6th International Conference on Industrial Engineering and Applications (ICIEA)*. 2019. Available from: DOI: 10.1109/IEA.2019.8714853

[8] WERBIŃSKA-WOJCIECHOWSKA, Sylwia, Technical system maintenance: delay-time-based modelling. *Springer Series in Reliability Engineering,* Cham: Springer, cop. 2019

[9] TUBIS, Agnieszka. Process assessment of risks in the production company with the use of linguistic variables and the FMEA analysis. In *Intelligent Systems in Production Engineering and Maintenance - ISPEM 2017 : proceedings of the First International Conference on Intelligent Systems in Production Engineering and Maintenance ISPEM 2017*, 2018, pp. 368-379

[10] TUBIS, Agnieszka and WERBIŃSKA-WOJCIECHOWSKA, Sylwia. 2013, Inventory management of operational materials in road passenger transportation company - case study. In *Carpathian Logistics Congress, CLC' 2013: Cracow, Poland, December 9th-11th 2013*. 2013, pp.1-6.

[11] ZHANG, Lixiang and HU, Yaoguang. Research on hybrid-load AGV dispatching problem for mixed-model automobile assembly line. *Procedia CIRP*. 2019. Vol. 81, pp. 1059-1064

[12] ZHANG, Zheng, GUO, Qing, CHEN, Juan and YUAN, Peijiang. Collision-Free Route Planning for Multiple AGVs in an Automated Warehouse Based on Collision Classification. *IEEE Access*. 2018. Vol. 6, pp. 26022 - 26035. Available from: DOI 10.1109/ACCESS.2018.2819199

[13] HRUŠECKÁ, Denisa, BORGES, Rui and JUŘIČKOVÁ, Eva. Challenges in the introduction of AGVS in production lines: Case studies in the automotive industry. *Serbian Journal of Management*. 2019. Vol. 14, no. 1

[14] CAPRILI, Silvia, MORELLI, Francesco, SALVATORE, Walter and NATALI, Agnese. Design and analysis of automated rack supported warehouses. *The Open Civil Engineering Journal*. 2018. Vol, 12, pp. 150-166

[15] WANG, Yanyan, ZHANG, Rongxu LIU, Hui, ZHANG, Xiaoqing and LIU Ziwei. Task scheduling model of double-deep multi-tier shuttle system. *Computer Science*. 2019. Available from: DOI:10.3390/pr7090604

[16] ZHAO, Xiaofeng, WANG, Yanyan, WANG, Yunge and HUANG, Ke. Integer programming scheduling model for tier-to-tier shuttle-based storage and retrieval systems. *Processes*. vol. 7, no. 4

[17] LERHER Tone. Warehousing 4.0 by using shuttle-based storage and retrieval systems. *FME Transactions*. 2018. Vol. 46, no. 3, pp. 381-385

[18] BOYSEN, Nils, BRISKORN, Dirk, FEDTKE, Stefan and SCHMICKERATH, Marcel. Automated sortation conveyors: A survey from an operational research perspective. *European Journal of Operational Research*. 2019. Vol. 276, no. 3, pp. 796-815

[19] CHEN, James C., HUANG, Chien-Fu, CHEN, Tzu-Li and LEE Yu-Hsin. Solving a Sortation Conveyor Layout Design Problem with Simulation-optimization Approach, *IEEE 6th International Conference on Industrial Engineering and Applications (ICIEA)*. 2019. Available from: DOI 10.1109/IEA.2019.8715232

[20] XIAOFEI, Kou, GANGYAN, Xu and CHUANYUN, Yi. (2018) Belt-conveyor based efficient parallel storage system design and travel time model analysis. *International Journal of Production Research*, vol. 56, no. 23, pp. 7142-7159, Available from: DOI: 10.1080/00207543.2018.143678410

[21] XU, Lijuan and ZHU, Jie. Study on store-space assignment based on logistic AGV in e-commerce goods to person picking pattern. *AIP Conference Proceedings*. 2017. Vol. 1890

[22] WANG, Yanyan, ZHOU, Y., SHEN, C. and WU, Y. Applicability Selection Method of Two Parts-to-picker Order Picking Systems. *Journal of Mechanical Engineering*. 2015, vol. 51, no. 4

[23] BOYSEN, Nils, DE KOSTER, René and WEIDINGER, Felix. Warehousing in the e-commerce era: A survey. *European Journal of Operational Research*. 2019. vol. 277, no. 2, pp. 396-411

[24] GAJŠEK, Brigita, ĐUKIĆ, Goran, OPETUK, Tihomir and CAJNER, Hrvoje. Human in Manual Order Picking Systems. *Computer Science*. 2017

[25] GROSSE, Eric, GLOCK, Christoph and NEUMANN, Patrick. Human factors in order picking: a content analysis of the literature, *IFAC-PapersOnLine*. 2015. vol. 48, no. 3, pp. 320-325. Available from: https://doi.org/10.1016/j.ifacol.2015.06.101

[26] BARTHOLDI, John and HACKMAN, Steven. Warehouse and Distribution Science, Georgia Institute of Technology, Atlanta, 2012, p. 25

[27] KOWALSKI, Marcin, MAGOTT, Jan, NOWAKOWSKI, Tomasz and WERBIŃSKA-WOJCIECHOWSKA, Sylwia., Exact and approximation methods for dependability assessment of tram systems with time window. *European Journal of Operational Research*. 2014, vol. 235, no.3, pp. 671-686

[28] HAŁADYN, Szymon, RESTEL, Franciszek and WOLNIEWICZ, Łukasz: Method for railway timetable evaluation in terms of random infrastructure load. In: *Engineering in dependability of computer systems and networks : proceedings of the Fourteenth International Conference on Dependability of Computer Systems DepCoS-RELCOMEX, July 1-5, 2019, Brunów, Poland.* 2020., pp. 235-244

[29] RESTEL, Franciszek and WOLNIEWICZ, Łukasz. Factors affecting the efficiency indicator of the public transport system : case study. In *Reliability and statistics in transportation and communication : selected papers from the 18th International Conference on Reliability and Statistics in Transportation and Communication, RelStat'18, 17-20 October 2018, Riga, Latvia*. 2019, pp. 57-68

[30] FRIEDRICH, Johannes and RESTEL, Franciszek. A fuzzy approach for evaluation of reconfiguration actions after unwanted events in the railway system. In *Engineering in dependability of computer systems and networks: proceedings of the Fourteenth International Conference on Dependability of Computer Systems DepCoS-RELCOMEX, July 1-5, 2019, Brunów, Poland*. 2020, pp. 195-204

[31] RESTEL, Franciszek and WOLNIEWICZ, Łukasz. Tramway reliability and safety influencing factors *Procedia Engineering*. 2017. vol. 187, pp. 477-482

[32] DOUDKIN, Mikhail, KIM, Alina, KIM, Vadim, MLYNCZAK, Marek, KUSTAREV, Gennady (2019) Computer Modeling Application for Analysis of Stress-Strain State of Vibroscreen Feed Elements by Finite Elements Method. In: Shokin Y., Shaimardanov Z. (eds) *Computational and Information Technologies in Science, Engineering and Education. CITech 2018*. *Communications in Computer and Information Science*. 2019. vol 998. Springer, Cham

[33] BOSTANOV B., TEMIRBEKOV E., DUDKIN Mikhail and KIM Alina. Mechanics-Mathematical Model of Conjugation of a Part of a Trajectory with Conditions of Continuity, Touch and Smoothness. In: Shokin Y., Shaimardanov Z. (eds) *Computational and Information Technologies in Science, Engineering and Education. CITech 2018. Communications in Computer and Information Science*. 2019. vol. 998. Springer, Cham

[34] KIERZKOWSKI, Artur and KISIEL, Tomasz. Functional Readiness of the Security Control System at an Airport with Single-Report Streams. *Advances in Intelligent Systems and Computing*. 2015. vol. 365. pp. 211-221. Available from: doi:10.1007/978-3-319-19216-1_20

[35] KIERZKOWSKI, Artur and KISIEL, Tomasz. 2016. Airport Security Screeners Reliability Analysis. In *IEEE International Conference on Industrial Engineering and Engineering Management*. 2016. pp. 1158-1163. Available from: doi:10.1109/IEEM.2015.7385830

[36] KIERZKOWSKI, Artur and KISIEL, Tomasz. Functional Readiness of the Check-in Desk System at an Airport. *Advances in Intelligent Systems and Computing*. 2015. vol. 365. pp. 223-233. Available from: doi:10.1007/978-3-319-19216-1_21

[37] KIERZKOWSKI, Artur and KISIEL, Tomasz. 2015. Modelling the Passenger Flow at an Airport Terminal to Increase the Safety Level. In *5th International Conference on Military Technologies, ICMT 2015, Brno, Czech Republic*. Available from: doi:10.1109/MILTECHS.2015.7153693

[38] KIERZKOWSKI, Artur and KISIEL, Tomasz. 2015. Simulation Model of Logistic Support for Functioning of Ground Handling Agent, Taking into Account a Random Time of Aircrafts Arrival. 2015. In *5th International Conference on Military Technologies*. Available from: doi:10.1109/MILTECHS.2015.7153694