MODEL OF DYNAMIC FUNCTIONING OF THE CHECK-IN DESK SYSTEM AT AN AIRPORT

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Abstract

The check-in system is the key element of airport operation. A vast majority of passengers must have the possibility of checking in the registered baggage and receiving a boarding card. The article presents a model of the functioning of the check-in desk system at an airport. This model is based on the model of the passenger service process at the check-in desk and an algorithm for the management of the schedule of the check-in desk operation. Input data for the model include: the check-in structure (distribution of the check-in system, characteristics of check-in desks), check-in procedures (common, dedicated, mixed), the flight schedule, on the basis of which the stream of passenger reports for the check-in is determined. The developed model allows the determination of the average passenger wait time for the check-in, depending on the check-in desk management strategy. The developed model was implemented into the Flexsim Software. The model was verified for the check-in system at the Wroclaw Airport. The developed model can also be used for the assessment of the functioning of both existing and designed check-in systems.

Keywords: airports, check-in, management, simulation model.

1. INTRODUCTION

The aspect of the airport operation in the world's literature focuses on the operation of various subsystems. A large number of studies are devoted to ramp services for aircraft. Authors of [1] developed a simulation model of the passenger-boarding process. On the basis of the analysis conducted, the authors showed the possibility of choosing an appropriate boarding strategy to reduce the boarding time. Author of [2] developed a simulation model, which allows an analysis of identification of passenger congestion in the aircraft door, depending on various boarding scenarios. Authors of [3] performed an analysis pertaining to the time of waiting for latecomers in the boarding process. In the article [4], ground handling was analysed as a sub-process in aircraft rotations. By analysing historical data, the authors determined the probability of delays in the ground-handling process due to individual handling sub-processes. On the basis of research and observations, Authors of [5] developed a set of practical recommendations, which can improve ground-handling efficiency. One of the more interesting issues in the ground-handling planning was presented by [6]. The system makes it possible to provide short-term support to process management. The objective function is based on three factors: the cost, energy and time consumption. Authors of [7] developed an algorithm for the allocation of technical and human resources to the implementation of individual ground-handling activities. The main assumption of the developed heuristic method is the division of resources into groups allocated to the ground handling of a given aircraft. Authors of [8] in the developed method for aircraft scheduling in the terminal control area using the rolling horizon approach, showed that the ground-handling planning according to the branch and bound strategy is the most effective. Such an approach makes it possible to achieve much higher efficiency that the first-come-first-served strategy.

Characteristics of the check-in system operation planning were described by [9]. Authors presented a model of determining the hourly capacity of the check-in desk system. The model of the check-in desk system was also presented in [10]. Today, many articles discuss the application of fuzzy logic for the modelling of complex systems [11]. In this work, reliability of the technical system [12] and aspects of vulnerability [13] will also be taken into account. A dependence functioning model of the systems will be developed, as in [14].

In the global aspect, the issue of the reliability of transport systems were brought upon on numerous occasions [15-20]. Issues related to the modelling of the reliability of a railway transport network system are presented in [21]. Simulation models of the operation of complex operation systems are presented in [22]. An assessment of the functioning of an intermodal transport system was presented in [23-24]. Important aspects taking into account energy consumption were presented in [25]. The use of Markov processes for the purposes of the modelling of reliability of transport systems is described in [26-27].

According to data presented by the Central Office for Delay Analysis [28] in Europe, as many as 37.4% of airport operations during the departure are delayed by more than 5 minutes. The average delay for delayed air operations is 26 minutes. The passenger-and-baggage check-in is one of the factors causing the largest number of delays during an operational day. Therefore, it is necessary to continuously develop the infrastructure of the system, taking into account the research aimed at obtaining the maximum effectiveness of the operation of the system. In the article, an approach to the check-in system modelling was presented, which takes into account the possibility of using the common check-in strategy in the implementation of the process.

2. MODEL OF DYNAMIC FUNCTIONING OF THE CHECK-IN DESK SYSTEM AT AN AIRPORT

This section presents a model of the functioning of the check-in desk system at an airport. The model was then implemented in the Flexsim environment. The possibility of the modelling of both discreet and continuous processes is an advantage of the software used. Also, the possibility of importing CAD files as well as the creation of libraries for subsequent use and the possibility of 3D process visualization is a significant advantage of the software used.

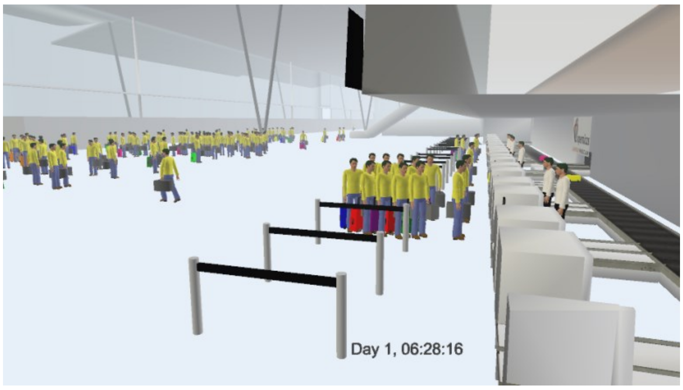

Fig. 1 Visualization of the check-in system

Model of the functioning of the check-in desk system at an airport is presented in Figure 2.

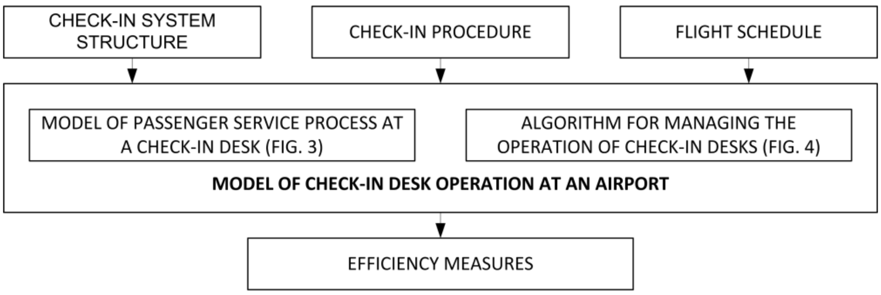

Fig. 2 Model of the functioning of the check-in desk system at an airport

Input data for the model include: the check-in structure (distribution of the check-in system, characteristics of check-in desks), check-in procedures (common, dedicated, mixed), the flight schedule, on the basis of which the stream of passenger reports for the check-in is determined.

The model of the functioning of the check-in desk system at an airport is based on the model of the passenger service process at the check-in desk (Figure 3) and an algorithm for the management of the schedule of the check-in desk operation (Figure 4).

The developed model of the check-in system functioning at the airport makes it possible to determine, amongst other things, the passenger's average wait time for the check-in at time t, taking into account the type of the carrier (FC – flag carriers, LC – low-cost carriers, CH – charter carriers).

The model of the passenger service at the check-in desk is presented in Figure 3.

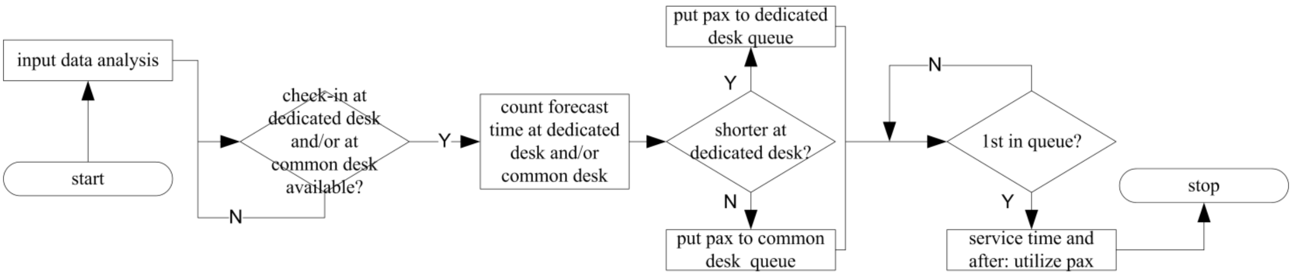

Fig. 3 Model of the passenger service process at the check-in desk at an airport

Input data is entered at the initial stage. The stream of passenger reports on the basis of the flight schedule and characteristics presented in [29] is defined. The handling procedure method is defined (common, dedicated, mixed). It is checked whether the passenger reporting for the check-in can start the check-in process at the carrier's or flight's dedicated desk. If the check-in has not started yet, it is checked whether the common check-in desk for all flights and carriers is open. If two of the conditions above are not met (the passenger's check-in for the flight has not started and the common check-in desk for all flights and carriers is not open), the passenger waits until one of the two events takes place. If one of these events (or two at the same time) is met, the passenger's predicted waiting time for the check-in is checked for the dedicated check-in desk and for the common check-in desk. The passenger is placed in the queue, in which the waiting time for the check-in is shorter. If the passenger is the first in the queue and the check-in desk is free, the check-in process begins in accordance with time characteristics presented in [29]. After the completion of the check-in, the passenger is placed in the waiting area for the security control system.

The algorithm for dynamic management of check-in desk system operation is presented in Figure 4.

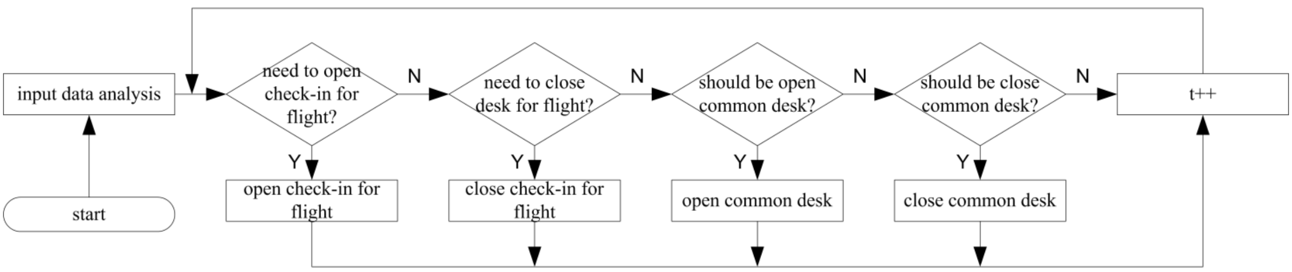

Fig. 4 The algorithm for dynamic management of check-in desk system operation

Input data is entered at the initial stage. The schedule of the check-in desk operation is indicated for individual flights (opening and closing times of check-in desks). The time of the simulation commencement is specified. In a given step of the simulation (at time t), it is checked whether it is necessary to open or close the check-in process for any of the flights from set F. If one of the events takes place, the check-in desks are opened or closed (in accordance with the carrier's requirements). The airport can decide to open a common check-in desk, which means that it will be possible to check in outside the opening hours of the carrier's dedicated check-in desk (the carrier's flights). The condition for opening of a common check-in desk can be the presence of a large group of passengers of various carriers, which are not checked in at time t. A similar condition for the opening of this check-in desk can be a situation, in which a large stream of passenger reports occurs for several check-in processes. If conditions for the opening of such a desk occur, it is opened. Otherwise, the desk is closed. However, it should be remembered that each carrier defines when the passenger must go through the check-in before the planned departure time. Passengers can check in at the latest 30 minutes before the planned departure time for flag carriers and 40 minutes before the flight for low-cost carriers.

3. MODEL APPLICATION AND VERIFICATION: THE WROCLAW AIRPORT

The check-in system is based on 21 desks, where passengers are served by GHA employees. Desk 1 is intended for oversized baggage, which means that no regular passenger service is performed there. The diagram of the check-in system is presented in Figure 5.

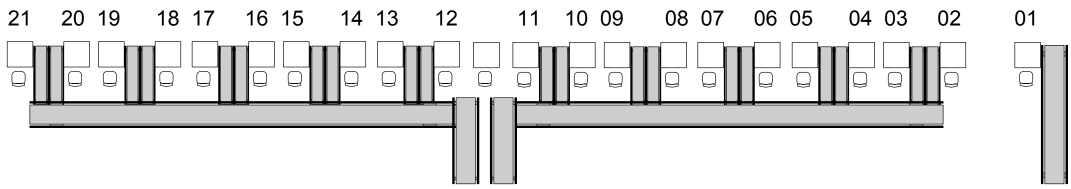

Fig. 5 Diagram of the check-in system at the Wroclaw Airport

At check-in desks, all three handling procedures (common, dedicated, mixed) can be performed; however, due to traffic intensity, it performs a dedicated procedure for the carrier.

The verification of the model was performed for the distribution of characteristics presented in (Kierzkowski Kisiel JOATM) and the flight schedule in Table 1.

The model of the functioning of the check-in system at the airport was verified by checking the consistency between the empirical and theoretical distributions (obtained from the model): times between passenger reports to the check-in system ($F_{INP}(t)$), times between the passengers leaving the check-in system ($F_{OUT}(t)$). The distributions are presented in Figure 6.

The λ-Kolmogorov consistency test was used to verify the consistency of empirical distributions (obtained as a result of research conducted at the airport) and theoretical ones (obtained from the simulation model). Consistency between distributions was revealed at the significance level of α=0.05. The obtained statistical value is lower than λ=1.36.

Table 1 Flight schedule (carrier type, planned departure time, number of passengers)

Type/no.	departure	pax	type	departure	pax	type	departure	pax
CH01	05:40	129	LC05	12:40	179	FC08	17:55	178
FC01	05:50	180	CH04	13:20	187	CH07	18:25	59
LC01	06:10	133	CH05	14:10	189	LC10	19:05	189
FC02	06:25	172	FC05	14:35	68	CH08	20:05	172
LC02	07:00	188	FC06	14:55	133	CH09	20:45	174
FC03	08:55	32	LC06	15:50	176	LC11	20:50	177
LC03	09:35	57	CH06	15:55	68	LC12	20:55	51
CH02	10:05	42	LC07	16:25	187	FC09	21:00	83
LC04	11:30	172	LC08	16:45	84	FC10	21:00	81
FC04	12:00	67	FC07	16:55	164	LC12	21:25	184
CH03	12:10	189	LC09	17:35	189	LC13	21:50	186

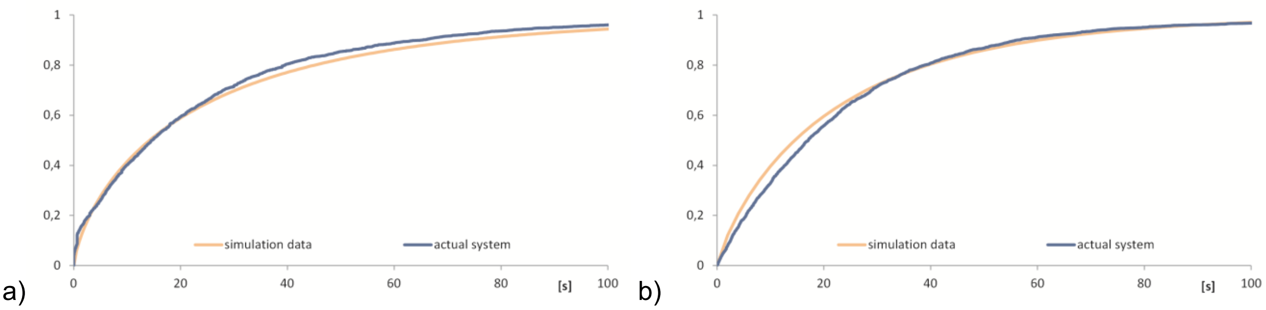

Fig. 6 Empirical and theoretical distribution functions: a) the number of passengers entering the check-in system, b) the number of passengers leaving the check-in system at 5-minute intervals

The developed model makes it possible to show the influence of the opening of a check-in desk on the passenger's waiting time for the check-in desk. Figure 7 presents the influence of the number of open common desks on the average waiting time for the check-in desk over the analysed day.

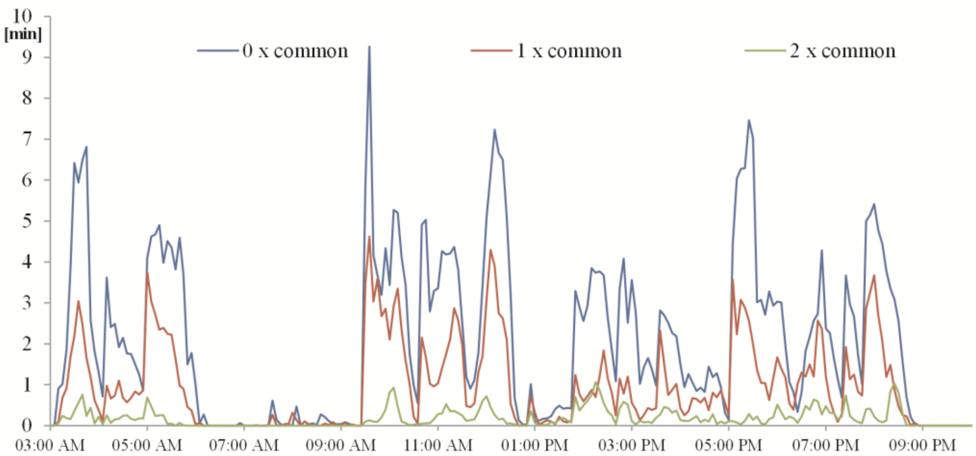

Fig. 7 Influence of the number of open common desks on the passenger's average waiting time for the desk.

The introduction of one common desk resulted in the reduction of the average passenger service time by half. It is important that this also occurred for the passenger's longest waiting time for the check-in. Accurate figures are presented in Table 2.

Table 2 Figures characterizing the check-in system operation according to the carrier type

	All carriers			Low cost carriers			Flag carriers			Charter carriers		
	Number of common check-in desks			Number of common check-in desks			Number of common check-in desks			Number of common check-in desks		
	0	1	2	0	1	2	0	1	2	0	1	2
Average waiting time	2.28	1.19	0.27	2.97	0.94	0.29	0.93	0.44	0.25	2.47	2.17	0.13
Standard deviation	2.96	2.14	0.78	3.44	1.53	0.75	1.42	1.15	0.55	2.86	2.95	0.30
lower 95%	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
upper 95%	8.80	5.61	1.66	10.46	3.83	1.88	4.22	3.22	1.55	8.87	6.4	0.78

The opening of an additional common check-in desk significantly reduces the average passenger waiting time for the service. This is particularly noticeable for low-cost carriers and flag carriers. Also, the 95-percentile passenger service time is reduced. The introduction of another (second) common check-in desk allows further reduction in the passenger's wait time. The necessity of providing an additional employee to operate the desk is a disadvantage of such a method of management. It was assumed in analyses that common desks will be open from the first to last passenger (from 3:00 AM to 9:00 PM). The developed model also allows for temporary opening of a common check-in desk, which makes it possible to reduce the costs of employing a check-in desk employee.

4. CONCLUSION

The article presents a model of the functioning of the check-in desk system at an airport. This model makes it possible to determine the passenger's average wait time for the check-in, depending on the carrier type and also depending on the number of open common check-in desks. The model of the functioning of the check-in desk system is based on the model of the passenger service process at the check-in desk and an algorithm for the management of the schedule of the check-in desk operation. The developed model can be used in functioning systems and it can also be used for designing such systems. The model was verified on the basis of actual data obtained within research conducted at the Wroclaw Airport.

Further work will be performed to take into account relationships between the operation of the check-in system and the security control system. An algorithm for the optimization of operation of the security control system and the check-in system (two inter-dependent systems) with minimal labour consumption in the two subsystems.

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REFERENCES

[1] LANDEGHEM H., BEUSELINCK A. Reducing passenger boarding time in airplanes: A simulation based approach., European Journal of Operational Research, 2002, pp. 294–308.

[2] BAZARGAN M. A linear programming approach for aircraft boarding strategy., European Journal of Operational Research 183, 2007, pp. 394–411.

[3] SKORUPSKI J., WIERZBIŃSKA M. A method to evaluate the time of waiting for a late passenger ., Journal of Air Transport Management, Vol. 47, 2015, pp. 79-89

[4] WU C-L., CAVES R. Modelling of aircraft rotation in a multiple airport environment., Transportation Research Part E 38, 2002, pp. 265–277.

[5] NUGROHO I., RIASTUTI U., IRIDIASTADI H. Performance Improvement Suggestions for Ground Handling Using Lean Solutions Approach, International Congress on Interdisciplinary Business and Social Science 2012, Procedia - Social and Behavioral Sciences 65, pp. 462 – 467.

[6] Ansola P., Morenas J., Garcia A., Otamendi J. (2012), Distributed decision support system for airport ground handling management using WSN and MAS., Engineering Applications of Artificial Intelligence 25, 2012, pp. 544–553

[7] ANDREATTA G., GIOVANNI L., MONACI M. A fast heuristic for Airport Ground-Service Equipment-and-Staff Allocation, AIRO Winter 2013, Procedia - Social and Behavioral Sciences 108, 2014, pp. 26-36.

[8] SAMÀ M., D'ARIANO A., PACCIARELLI D. Rolling horizon approach for aircraft scheduling in the terminal control area of busy airports., Transportation Research Part E 60, 2013, pp. 140–155.

[9] KORAY KIYILDI R., KARASAHIN M. The capacity analysis of the check-in unit of Antalya Airport using the fuzzy logic method, Transportation Research Part A: Policy and Practice, Volume 42 (4): 2008, pp. 610-619

[10] BEVILACQUA M., CIARAPICA F.E. Analysis of check-in procedure using simulation: a case study. In: IEEE Int. Conf. Industrial Engineering and Engineering Management (IEEM): 2010, pp.1621–1625

[11] VALIS D., ZAK L., WALEK A., PIETRUCHA-URBANIK K. Selected mathematical functions used for operation data information (2014) Safety, Reliability and Risk Analysis: Beyond the Horizon - Proceedings of the European Safety and Reliability Conference, ESREL 2013, pp. 1303-1308

[12] JODEJKO-PIETRUCZUK A., PLEWA M., "The model of reusability of multi-component product", Advances in Safety, Reliability and Risk Management - Proceedings of the European Safety and Reliability Conference, ESREL 2011, pp. 2096-2102

[13] VINTR Z., VALIS D., Malach, J. Attack tree-based evaluation of physical protection systems vulnerability (2012) Proceedings - International Carnahan Conference on Security Technology, art. no. 6393538, pp. 59-65

[14] VINTR Z., VALIS D. Modeling and analysis of the reliability of systems with one-shot items. 2007 Proceedings - Annual Reliability and Maintainability Symposium, RAMS, art. no. 4126381, pp. 380-385

[15] NOWAKOWSKI T., TUBIS A, WERBINSKA-WOJCIECHOWSKA S. Maintenance decision making process - a case study of passenger transportation company W: Theory and engineering of complex systems and dependability : proceedings of the Tenth International Conference on Dependability and Complex Systems DepCoS-RELCOMEX, June 29 - July 3, 2015, Brunów, Poland / Wojciech Zamojski [i in.] (eds.). Springer, cop. 2015. s. 305-318

[16] NOWAKOWSKI T., ZAJAC M. Analysis of reliability model of combined transportation system. Proceedings of conference ESREL, 2005

[17] ZAJAC M., SWIEBODA J. Initial FMEA analysis of the container transport chain. Source of the Document Safety and Reliability: Methodology and Applications - Proceedings of the European Safety and Reliability Conference, ESREL 2014

[18] TUBIS A, WERBINSKA-WOJCIECHOWSKA S Concept of controlling for maintenance management performance: a case study of passenger transportation company. W: Safety and reliability of complex engineered systems proceedings of the 25th European Safety and Reliability Conference, ESREL 2015, Zurich, Switzerland, 7-10 September 2015 / eds. Luca Podofillini I in.]. Boca Raton [i in.] : CRC Press/Balkema, cop. 2015. s. 1055-1063

[19] RESTEL F.J.: Impact of infrastructure type on reliability of railway transportation system. Journal of Konbin 25 (1), 2013, pp. 21-36

[20] KIERZKOWSKI A. Reliability models of transportation system of low cost airlines. Reliability, Risk and Safety: Back to the Future, 2010, pp. 1325-1329

[21] RESTEL F.J.: The Markov reliability and safety model of the railway transportation system. (2015) Safety and Reliability: Methodology and Applications - Proceedings of the European Safety and Reliability Conference, ESREL 2014

[22] GIEL R., MŁYŃCZAK M., PLEWA M. "Logistic support model for the sorting process of selectively collected municipal waste". Theory and engineering of complex systems and dependability: proceedings of the Tenth International Conference on Dependability and Complex Systems DepCoS-RELCOMEX, June 29 - July 3, 2015, Brunów, Poland. Springer, cop. 2015. s. 369-380.

[23] ZAJAC M., SWIEBODA J. Initial FMEA analysis of the container transport chain. Source of the Document Safety and Reliability: Methodology and Applications - Proceedings of the European Safety and Reliability Conference, ESREL 2014

[24] ZAJAC M., SWIEBODA J. Analysis of the process of unloading containers at the inland container terminal Source of the Document Safety and Reliability: Methodology and Applications - Proceedings of the European Safety and Reliability Conference, ESREL 2014

[25] ZAJĄC P. Transport-storage system optimization in terms of exergy. (2010) International Conference on Harbour, Maritime and Multimodal Logistics Modelling and Simulation 1, pp. 143-148

[26] ZAJAC M., KIERZKOWSKI A. Uncertainty assessment in semi Markov methods for Weibull functions distributions. Advances in Safety, Reliability and Risk Management - Proceedings of the European Safety and Reliability Conference, ESREL 2011, 2012, pp. 1161-1166

[27] KWASNIOWSKI S., ZAJAC M., ZAJAC P. Telematic problems of unmanned vehicles positioning at container terminals and warehouses. (2010) In Transport Systems Telematics, pp. 391-399

[28] EUROCONTROL, CODA DIGEST All-Causes Delay and Cancellations to Air Transport in Europe – 2014, EUROCONTROL, 2015.

[29] KIERZKOWSKI A., KISIEL T. Model of dynamic management of the check-in desk system at an airport. Journal of Air Transport Management, 2015 (in. prep.)