A MULTI-CRITERIA MODEL FOR THE ASSESSMENT OF THE CHECKED BAGGAGE CLAIM PROCESS AT THE AIRPORT

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Abstract

The aim of the article was to develop a model for assessing the quality of service in the area of baggage claim at the airport. The aim was achieved by building an evaluation model based on fuzzy logic. Three criteria were taken into account. The first one concerns the time of baggage collection. The second criterion was related to baggage damage. The third criterion results from the space in the baggage claim area. This model is a response to the problem of modelling the baggage claim area and problems related to mishandled bags. There were currently no assessment models available that would present the passenger's point of view. This model offers many advantages that allow the airport manager to check whether the system is working properly at the airport or whether corrective actions need to be implemented.

Keywords: Baggage handling, level of service, airport

1. INTRODUCTION

Nowadays, transport systems have to meet many requirements [1]. We refer here to a few works of scientific literature, which emphasize the importance of all issues. Transport systems should be: efficient [2-5], safe [6-10], reliable [11-17] and environmentally friendly [18-20].

It should also be borne in mind that well-designed systems are robust against various types of disturbances [21]. Therefore, the scientific work has to meet very important requirements. It is often the case that scientific studies are carried out a multi-criteria assessment [22,23].

It is important not only to ensure adequate performance, security, etc., but also to look at the systems from the point of view of their user [24]. It is therefore important to consider the level of service as an output indicator [25]. Therefore, this work will focus on this assessment of one of the airport's handling processes.

In this work, an issue of great importance for air transport passengers will be addressed. This passenger requires the handling system to ensure that the baggage is delivered on the same flight, is undamaged and can be picked up quickly.

We present a model in which the phenomenon of mishandled bag is assessed from the point of view of the passenger. On this basis, the airport will know whether its system is working properly. In chapters 1.1. and 1.2. we show that it has not been developed yet and that it is a very serious issue to be solved.

1.1. Statistical data

Over the last ten years, the baggage transport system in air transport has been significantly improved (see **Figure 1**). The total number of mishandled bags decreased by as much as 51.5 % and the number of mishandled bags per 1,000 passengers decreased by 70.5 % [26].

Given the high dynamics of the number of passengers handled over the period (64 % increase from 2.48 to 4.08 billion passengers handled), the rate of incorrectly handled baggage per 1000 passengers reflects to a greater extent the scale of the improvements made [26].

The most dynamic rate of improvement can be seen between 2007 and 2014. The number of incorrectly checked baggage per 1,000 passengers decreased by as much as 61.3 %. In the last reported year, the number of incorrectly handled baggage per 1,000 passengers decreased by only 3 % (5.73 to 5.57).

According to [27], mishandled bag is lost, delayed or damaged bag. The current [26] report on baggage handling issues in air transport indicates that in 2017 as many as 22.7 million baggage was incorrectly handled. New tools should therefore be developed to significantly reduce the number of errors that occur during baggage handling in air transport.

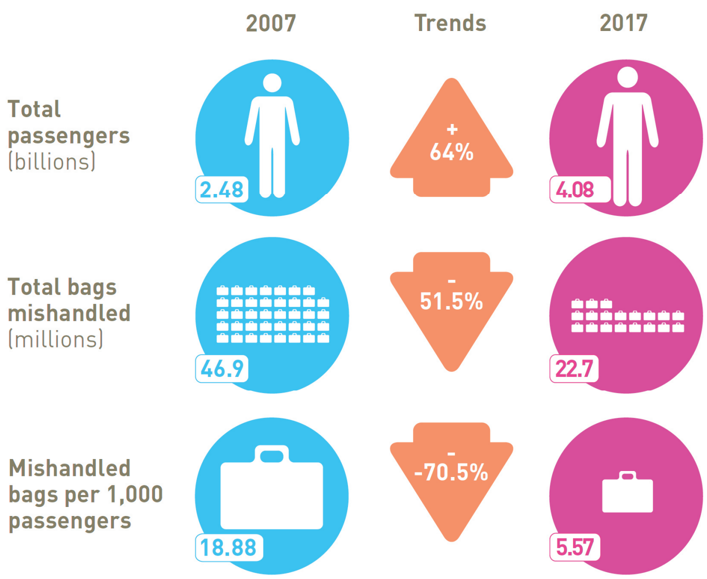

Figure 1 Long term trends for mishandled bags [26]

1.2. State of the art

The Airport Development Reference Manual [28] presents recommendations for airports in terms of passenger level of service. These assumptions allow the airport to be classified into one of six service quality categories. It takes into account the space in the terminal as well as the time of passenger service in the queuing systems. IATA users benefit from this evaluation method. However, it does not allow the direct opinion of passengers to be known. However, it is estimated that up to 12 minutes is best to wait for baggage and up to 18 minutes is still acceptable.

Scientific works can be divided into two main categories. The first one allows to get to know the direct opinion of passengers on the level of service through a survey [29-31]. The authors focus on different evaluation criteria. Other parts of the infrastructure and its systems are also assessed.

The second group consists of scientific papers which allow for forecasting assessments for service systems. Linear regression methods, correlation coefficient, multiple regression, simulation methods or fuzzy logic are used [32-36].

Very different aspects were raised: waiting time to the station, service time, kindness of staff, availability of baggage carts, waiting time for security check, reliability of controls, being safe, thermal comfort, acoustic comfort, cleanliness of the terminal, availability of toilets, prices of services on the terminal. However, these methods were not focused in detail on the subsequent service subsystems. In this article there will be a specific consideration of the baggage collection process only, which allows a precise assessment of this subsystem.

There is a lot of scientific work on the Baggage Handling System (BHS) at the airport. However, they are more or less focused on the proper functioning of the system in terms of efficiency and safety.

For example, [37] in microscopic terms carried out the investigation into the design and control of merging bottlenecks of conveyor-based baggage handling systems, encompassing the merging control algorithm and the impact of the merge's physical layout. In turn [38] shows how to model and design the entire BHS at the airport. In these two works, computer simulation methods were used.

In addition, issues related to the operation and maintenance of BHS [39] show that in terms of the design and maintenance of the BHS system there is a great deal of knowledge. There are also works that suggest how to schedule tasks for the BHS [40].

It should also be noted here that one of the main objectives of BHS systems is to ensure safety. This area has already been well explored [41].

The statistics on mishandled bags presented in chapter 1.1. made the whole process of baggage travel interesting. Implementation Guide to Resolution 753/A4A Resolution 30.53 [27] have led to the development of effective methods for tracking baggage. This allows to identify where the baggage was lost or delayed. In this aspect, solutions related to baggage tracking via RFID are proposed [42].

The scientific work lacks consideration of whether the designed and operated baggage handling systems meet the requirements from the point of view of passengers. This article deals with this issue.

2. MODEL FOR THE ASSESSMENT OF THE CHECKED BAGGAGE CLAIM PROCESS AT THE AIRPORT

On the basis of the conducted research, three key criteria for assessing the baggage collection system at the airport were distinguished:

- waiting time for baggage collection,
- degree of damage to baggage,
- space per passenger in the baggage claim area.

The waiting time criteria and the space per passenger in the baggage claim (BC) area are natural criteria in the process of evaluating the hold baggage claim system. It is quite surprising that passengers qualify for the assessment of the baggage claim system for the degree of damage to baggage. Indeed, damage to baggage may occur at the airport of departure or in the ground handling process at intermediate airports. However, the research showed that the passenger blames the destination airport for the situation.

Thus, the following linguistic input variables for the system evaluation were adopted:

X_{wt} - waiting time for baggage claim,

X_{dam} - degree of damage to baggage,

X_{spa} - the space in the baggage claim area per passenger.

As the linguistic output variable, the BC - Y_{bc} system evaluation was adopted. The general concept of the model is shown in **Figure 2**.

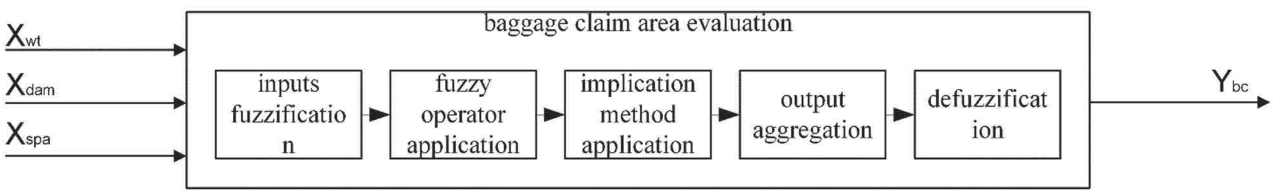

Figure 2 The concept of the model of evaluation of a baggage claim area

Membership functions were adopted for input data and are presented in **Figure 3**. It was assumed that each of the variables can be at a low or a high level. The waiting time for baggage claim is described as the time from the moment the passenger arrives at the baggage claim area to the moment the baggage is collected (measured in minutes). The degree of damage to the baggage is described as the percentage of damage to the baggage. As part of the survey, the acceptable level of damage to baggage (including scratches on the suitcase) was estimated. Similarly, the survey estimated the level of space per passenger. A membership function of output linguistic variable was represented by a low, average or high rate (**Figure 4**.).

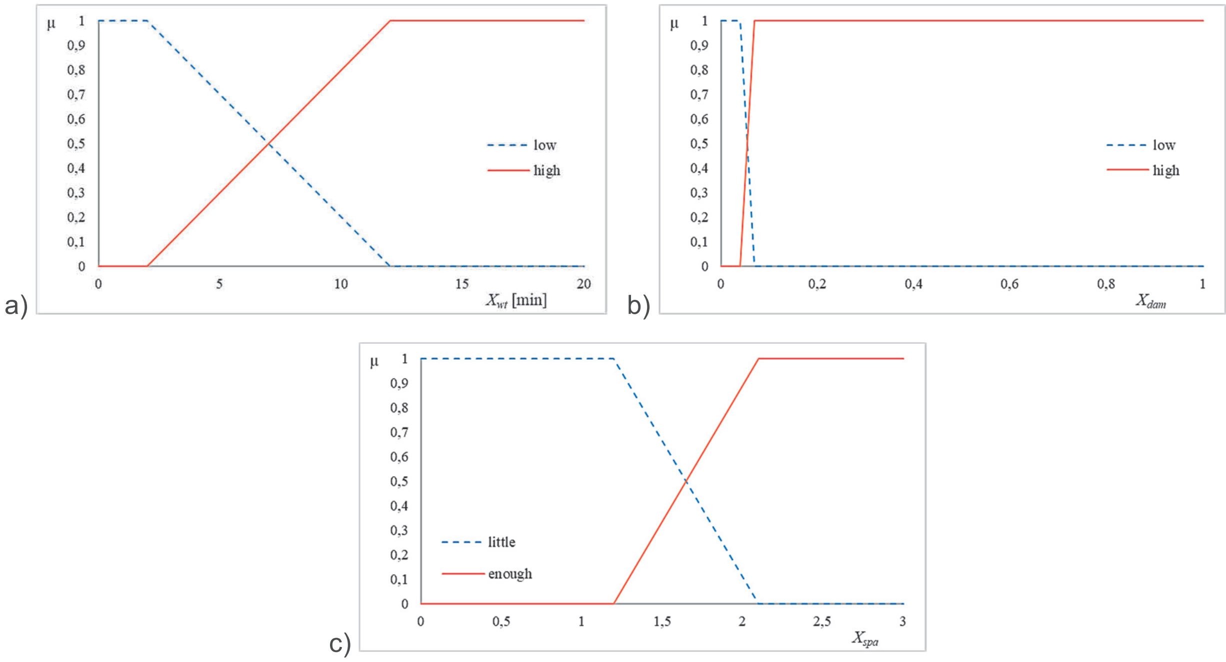

Figure 3 Membership functions of the input linguistic variables:
(a) waiting time for baggage claim, (b) degree of damage to baggage, (c) the space in the baggage claim area per passenger

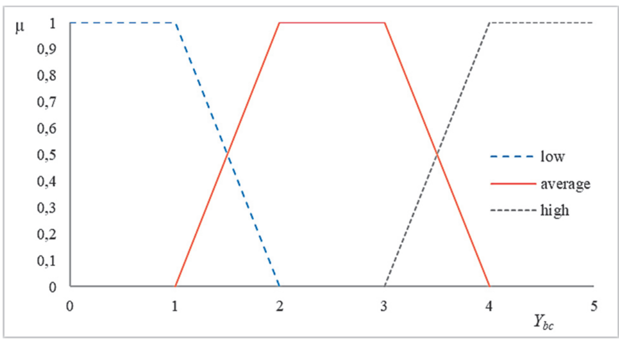

Figure 4 Membership functions of the output linguistic variable of evaluation of the baggage claim area

Fuzzy operators are used to define the method of carrying out of a logical operation. Operators AND or OR can be used. In case of a logical product of A AND B, the most frequently function used is min (A, B) which determinates the minimum value of the A and B membership function. The situation is similar in case of the OR operator, where max (A, B) is determined, that is the highest value of the A and B membership function.

Implication method application is done in two steps. In the first step, rules are developed. Weight can be assigned to each rule. It will decide about the rules significance. In the example shown, the weight is the same for all rules.

A set of rules can be as follows:

R1: If (X_{wt} is high) and (X_{spa} is low) and (X_{dam} is low), then (Y_{bc} is low)

R2: If (X_{wt} is low) and (X_{spa} is high) and (X_{dam} is high), then (Y_{bc} is high)

R3: If (X_{wt} is low) and (X_{spa} is low), then (Y_{bc} is average)

R4: If (X_{wt} is high) and (X_{spa} is high), then (Y_{bc} is average)

R5: If (X_{wt} is high) and (X_{dam} is high), then (Y_{bc} is average)

R6: If (X_{wt} is low) and (X_{dam} is low), then (Y_{bc} is average)

R7: If (X_{spa} is low) and (X_{dam} is high), then (Y_{bc} is average)

R8: If (X_{spa} is high) and (X_{dam} is low), then (Y_{bc} is average)

On the basis of the rules adopted together with input membership functions, an output membership function is determined for each rule $\mu_{out}^{R1}(z), \mu_{out}^{R2}(z), \ldots, \mu_{out}^{R8}(z)$. In case of the method developed, the minimum function was proposed to be applied in case of the output membership function. It has been applied in the majority of research papers. Aggregation of all outputs means an algebraic combination of all output membership functions. In order to do it, the maximum function for all output membership functions has to be calculated (1).

$$\mu_{out}(z) = max\{\mu_{out}^{R1}(z), \mu_{out}^{R2}(z), \ldots, \mu_{out}^{R8}(z)\} \quad (1)$$

The last step is the defuzzification process. It is usually based on determination of a centroid of output membership functions on the basis of the following formula (2)

$$z^* = \frac{\int \mu_{out}(z) \cdot z dz}{\int \mu_{out}(z) dz} \quad (2)$$

By using the MATLAB software, it is possible to determine two-dimensional variables of the dependency of the space and waiting time on the evaluation of a baggage claim area (**Figure 5**.).

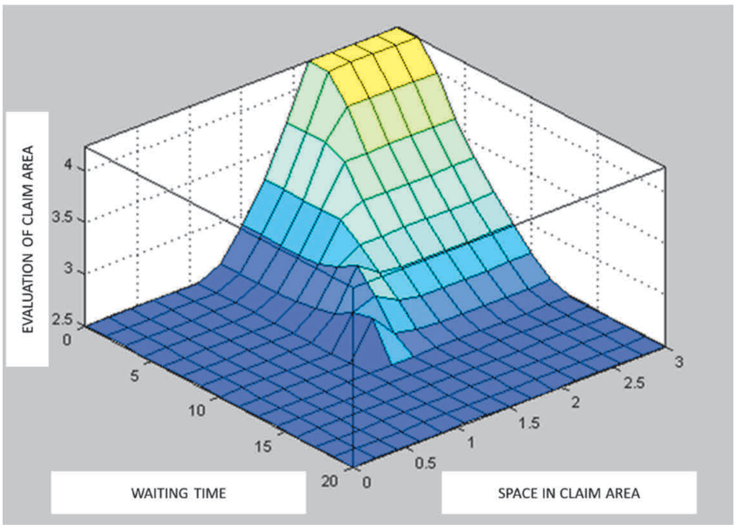

Figure 5 Dependency of LOS and capacity on the evaluation of a baggage claim area

It should be noted that if the rather regressive requirements for passenger handling in the baggage claim area are met: a waiting time of less than 2 minutes and a passenger space of more than 2 m^2 per passenger can be given a maximum performance rating for this area. Waiting for baggage above 13 minutes results in the lowest rating for this system as well as for the space per passenger below 1 m^2.

3. CONCLUSION

The developed model enables the assessment of the system of baggage claim in the airport. For the purpose of developing input variables, research was conducted on the basis of the real system. The developed model is a universal model that can be applied at any airport. One of the conditions of application of the model is to develop the function of belonging depending on the preferences of passengers.

REFERENCES

[1] STRAKA, M., LENORT, R., KHOURI, S., and FELIKS, J. Design Of Large-Scale Logistics Systems Using Computer Simulation Hierarchic Structure. *International Journal Of Simulation Modelling.* 2018. Vol.17. Issue 1. pp: 105-118.

[2] JODEJKO-PIETRUCZUK, A., NOWAKOWSKI, T., WERBIŃSKA-WOJCIECHOWSKA, S. Issues of multi-stated logistic support system performing in a system of systems. In: *Carpathian Logistics Congress, CLC' 2013*, Cracow, Poland, Ostrava: Tanger, 2013, pp. 1-6

[3] HAŁADYN, S., RESTEL, F., WOLNIEWICZ, Ł. Method for railway timetable evaluation in terms of random infrastructure. In: Zamojski W., Mazurkiewicz J., Sugier J., Walkowiak T., Kacprzyk J. (eds) *Engineering in Dependability of Computer Systems and Networks. DepCoS-RELCOMEX 2019*. Advances in Intelligent Systems and Computing. Springer, Cham. 2020. vol. 987. pp. 235-244

[4] FRIEDRICH, J., RESTEL, F.J., WOLNIEWICZ, Ł. Railway Operation Schedule Evaluation with Respect to the System Robustness. In: Zamojski W., Mazurkiewicz J., Sugier J., Walkowiak T., Kacprzyk J. (eds) *Contemporary Complex Systems and Their Dependability. DepCoS-RELCOMEX 2018*. Advances in Intelligent Systems and Computing. Springer, Cham. 2019. vol 761. pp. 195-208

[5] TUBIS, A., WERBIŃSKA-WOJCIECHOWSKA, S. Balanced Scorecard use in passenger transport companies performing at Polish market. *Procedia Engineering*. 2017. vol. 187. pp. 538-547

[6] SKORUPSKI, J., UCHROŃSKI, P., Managing the process of passenger security control at an airport using the fuzzy inference system, *Expert Systems with Applications*. 2015. Vol. 54. pp. 284-293

[7] TUBIS, A., Information needs of decision makers for risk assessment in road transport. In: Zamojski W., Mazurkiewicz J., Sugier J., Walkowiak T., Kacprzyk J. (eds) *Engineering in Dependability of Computer Systems and Networks. DepCoS-RELCOMEX 2019*. Advances in Intelligent Systems and Computing. Springer, Cham. 2020. vol 987. pp. 525-533.

[8] SKUPIEŃ, E., TUBIS, A., The use of linguistic variables and the FMEA analysis in risk assessment in inland navigation. *TransNav - The International Journal on Marine Navigation and Safety of Sea Transportation*. 2018. vol. 12, Issue 1. pp. 143-148.

[9] KRZYKOWSKA, K., SIERGIEJCZYK, M., ROSIŃSKI, A., The Concept of the SWIM System in Air Traffic Management, *Activities In Navigation: Marine Navigation And Safety Of Sea Transportation*. 2015. pp. 255-261

[10] TUBIS A., Route risk assessment for road transport companies. In: Zamojski W., Mazurkiewicz J., Sugier J., Walkowiak T., Kacprzyk J. (eds) *Contemporary Complex Systems and Their Dependability. DepCoS-RELCOMEX 2018*. Advances in Intelligent Systems and Computing. Springer, Cham. 2019. vol 761. pp. 492-503.

[11] RESTEL, F., WOLNIEWICZ, Ł. Tramway Reliability and Safety Influencing Factors. *Procedia Engineering*. 2017. Vol. 187. pp. 477-482

[12] DĄBROWSKA, A., GIEL, R., PLEWA, M.The Picking Process Model in e-Commerce Industry. In: Zamojski W., Mazurkiewicz J., Sugier J., Walkowiak T., Kacprzyk J. (eds) *Engineering in Dependability of Computer Systems and Networks. DepCoS-RELCOMEX 2019*. Advances in Intelligent Systems and Computing. Springer, Cham. 2020, vol 987. pp. 123-131

[13] FELIKS, J. A unified model of systems dependability and process continuity for complex supply chains, In: *Safety And Reliability: Methodology And Applications*, *Proceedings Of The European Safety And Reliability Conference (ESREL) 2014*, Crc Press-Taylor & Francis Group. 2015. pp. 2395-2403

[14] VINTR, Z., VALIS, D. Vehicle maintenance proces optimisation using life cycle costs data and reliability-centred maintenance. In: *Proceedings of the First International Conference on Maintenance Engineering*. 2006. pp. 180-188

[15] RESTEL, F., WOLNIEWICZ, Ł. Factors Affecting the Efficiency Indicator of the Public Transport System-Case Study. In: Kabashkin I., Yatskiv (Jackiva) I., Prentkovskis O. (eds) *Reliability and Statistics in Transportation and Communication. RelStat 2018*. Lecture Notes in Networks and Systems. Springer, Cham. 2019. vol 68. pp. 57-68

[16] JODEJKO-PIETRUCZUK, A., WERBIŃSKA-WOJCIECHOWSKA, S. Block inspection policy for non-series technical objects. In: *Safety, reliability and risk analysis: beyond the horizon: proceedings of the European Safety and Reliability Conference, ESREL 2013*, Amsterdam. Leiden: CRC Press/Balkema. 2014. pp. 889-898.

[17] NOWAKOWSKI, T., TUBIS, A., WERBIŃSKA-WOJCIECHOWSKA, S., Maintenance decision making process - a case study of passenger transportation company. In: Zamojski W., Mazurkiewicz J., Sugier J., Walkowiak T., Kacprzyk J. (eds) *Theory and Engineering of Complex Systems and Dependability. DepCoS-RELCOMEX 2015*. Advances in Intelligent Systems and Computing. Springer, Cham. vol 365. pp. 305-318.

[18] GIEL, R., PLEWA, M., The evaluation method of the process of municipal waste collection. In: *Carpathian Logistics Congress, CLC' 2015: conference proceedings*, Jesenik, Czech Republic. Ostrava : Tanger, cop. 2016. pp. 281-287

[19] GIEL, R., PLEWA, M., Analysis of the impact of changes in the size of the waste stream on the process of manual sorting of waste. In: Świątek J., Wilimowska Z., Borzemski L., Grzech A. (eds) *Information Systems Architecture and Technology: Proceedings of 37th International Conference on Information Systems Architecture and Technology - ISAT 2016 - Part III*. Advances in Intelligent Systems and Computing, Springer. Cham. 2017. vol 523. pp. 127-136

[20] BUJAK, A., ZAJĄC, P. Monitoring of Cargo in Logistic Systems of Transport and Storage. In: Mikulski J. (eds) *Activities of Transport Telematics. TST 2013*. Communications in Computer and Information Science. Springer. 2013. vol 395. pp. 361-369

[21] NOWAKOWSKI, T., WERBIŃSKA-WOJCIECHOWSKA, S. Data gathering problem in decision support system for means of transport maintenance processes performance development. In: *Safety, reliability and risk analysis: beyond the horizon: proceedings of the European Safety and Reliability Conference, ESREL 2013*, Amsterdam. Leiden: CRC Press/Balkema. 2014. pp. 899-907

[22] SKORUPSKI, J. Multi-criteria group decision making under uncertainty with application to air traffic safety. *Expert Systems with Applications*. 2014. Vol. 41. Issue 16. pp. 7406-7414

[23] GIEL, R., PLEWA, M. Route planning model in robotic system. In: *8th Carpathian Logistics Congress, CLC'2018 : conference proceedings*. Prague. Ostrava: Tanger. 2019. pp. 461-468

[24] KIERZKOWSKI, A., KISIEL, T., PAWLAK, M. A Method for Passenger Level of Service Estimation at the Airport Landside. In: Zamojski W., Mazurkiewicz J., Sugier J., Walkowiak T., Kacprzyk J. (eds) *Contemporary Complex Systems and Their Dependability. DepCoS-RELCOMEX 2018*. Advances in Intelligent Systems and Computing, Springer. 2019. vol 761. pp. 281-289

[25] KIERZKOWSKI, A., KISIEL, T., PAWLAK, M. Simulation Model of Check-in Management Regarding the IATA Level of Service Standards. In: Kabashkin I., Yatskiv (Jackiva) I., Prentkovskis O. (eds) *Reliability and Statistics in Transportation and Communication. RelStat 2018*. Lecture Notes in Networks and Systems, Springer, Cham. 2019. vol 68. pp. 150-158

[26] SITA. *The Baggage Report*. SITA. 2017. pp. 1-20

[27] IATA. *Baggage Tracking IATA Resolution 753/A4A Resolution 30.53 Implementation Guide*. IATA. 2017. pp. 1-85

[28] IATA. *Airport Development Reference Manual 10th Edition*, IATA. 2014. pp. 1-334

[29] BEZERRA, G.C.L., GOMES, C.F. The effects of service quality dimensions and passenger characteristics on passenger's overall satisfaction with an airport. *Journal of Air Transport Management*. 2015. Vol. 44. pp. 77-81

[30] LIOU, J.J.H., TANG, C.-H., YEH, W.-C., TSAI, C.-Y. A decision rules approach for improvement of airport service quality. *Expert Systems with Applications*. 2011. Vol. 38. Issue 11. pp. 13723-13730

[31] MAGRI, A.A., ALVES, C.J.P. Convenient airports: point of view of the passengers, In: *Proceedings of the 7th Air Transport Research Society World Conference*. Toulouse. France. 2003. pp. 1-10

[32] OMER, K.F., KHAN, A.M., Airport landside level of service estimation: utility theoretic approach. *Transportation Research Record 1199*. TRB. National Research Council. Washington. 1988. pp. 33-40

[33] CORREIA, A.R., WIRASINGHE, S.C., DE BARROS, A.G. A global index for level of service evaluation at airport passenger terminals. *Transportation Research Part E*. 2008. Vol. 44. Issue 4. pp. 607-620

[34] DE BARROS, A.G., SOMASUNDARASWARAN, A., WIRASINGHE, S.C. Evaluation of level of service for transfer passengers at airports. *Journal of Air Transport Management*. 2007. Vol. 13. Issue 5. pp. 293-298.

[35] KIERZKOWSKI, A., KISIEL, T., PAWLAK, M. Passenger level of service estimation model for queuing systems at the airport. *Archives of Transport*. 2018. vol. 47. No. 3. pp. 29-38

[36] YEN, J.-R., TENG, C.-R., CHEN, P.S. Measuring the Level o f Service at Airport Passenger Terminals: Comparison o f Perceived and Observed Time. *Transportation Research Record 1744*. TRB. National Research Council. Washington. 2001. pp. 17-23.

[37] JOHNSTONE, M. Simulation-based baggage handling system merge analysis. *Simulation Modelling Practice and Theory*. 2015. Vol. 53. pp. 45-59

[38] CAVADA, J., CORTÉS, C., REY, P., A simulation approach to modelling baggage handling systems at an international airport. *Simulation Modelling Practice and Theory*. 2017. Vol. 75. pp. 146-164

[39] SWARTJES, L., VAN BEEK, D.A., FOKKINK, W.J.., VAN EKELEN, J.A.W.M. Model-based design of supervisory controllers for baggage handling systems. *Simulation Modelling Practice and Theory*. 2017. Vol. 78. pp. 28-50

[40] ABDELGHANYA, A., ABDELGHANYB, K., NARASIMHAN, R., Scheduling baggage-handling facilities in congested airports. *Journal of Air Transport Management*. 2016. Vol. 12. pp. 76-81

[41] SKORUPSKI J., UCHROŃSKI P., A fuzzy system to support the configuration of baggage screening devices at an airport. *Expert Systems with Applications*. 2016. Vol. 44. pp. 114-125

[42] OUYANG, Y., HOU, Y., PANG, L., WANG, D, XIONG, Z., An Intelligent RFID Reader and its Application in Airport Baggage Handling System. In: *2008 4th International Conference on Wireless Communications, Networking and Mobile Computing*. Dalian. 2008. pp. 1-4