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Simulation Model for Optimizing the Parameters of Passengers Handling Process at Airports

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Abstract

In air transport, the majority of systems designed for passengers and baggage handling has the character of a multiphase system. Air traffic intensity requirements (passenger numbers) vary throughout the day, week, and year. When changing the conditions and requirements of practice, we need to determine the optimum capacity of these airport subsystems, properly dimensioning the subsystem capacity for each stage of passenger and baggage handling process. Individual airports aim to minimize passenger waiting times and their handling in order to seek a balance between passenger waiting times and costs associated with the achievement of this condition. The aim of the article is to optimize the passenger and baggage handling process at the selected airport using a simulation model.
KEY WORDS: *model, simulation, check-in, Rockwell Arena, optimization*

1. Introduction

Increasing demand for air transport causes congestion and various delays, which are becoming an increasingly common part of normal airport operations. Uncertainties associated with these problems make it difficult for airports, airlines and air traffic service providers to manage air traffic. Among other things, capacity congestion at airports also leads to significant financial and environmental inefficiencies. There are many problems and risks in the design and operation of complex transport systems. The complexity of problem evaluation, or the large number of variations, does not give the designer or manager a choice of optimal solution using classic tools. Given the uncertainty of the development and requirements of transport, time pressure, limited funding and the unavailability of modern tools, it is difficult to talk about overall system optimization. Therefore, it is very convenient to use high-tech techniques and technologies to help us solve such problems. These include computer modeling and simulation [1].

A lot of organizations and businesses deal with this issue applied to air transport. As a representative example, there are two cases. The Civil Engineering Department of Surabaya, Indonesia, has been investigating the congestion of services at the airport terminal, depending on the time when the process is being carried out. Flow data was collected at time intervals divided into time blocks dependent on the average operator time. The best time for such a division is 10 minutes, because IATA's passenger arrival distribution is based on 10 minute time intervals.

The method adopted in this research does not take into account the variability of service time. The variables that have been included in the calculation for the number of resources are service time, arrival curves, service line typology, and equipment costs. Optimization of this model is based on minimizing total costs of the system. Expected costs are the cost of space, operating costs and inconvenience costs that the passenger survived when the waiting time exceeded the allowable limit. By integrating space costs, it was possible to optimize the size of the terminal. The second example is a solution designed at Carleton University in Ontario, Canada, where a linear programming model has been designed to minimize the total working time at the check-in desks, ensuring a satisfactory level of customer service. The output of this simulation shows a significant improvement in performance by providing shorter line lengths, reducing waiting time, and increasing the percentage of satisfied customers [2, 6, 7].

The area of modeling, simulation and 3D visualization of simulation results is a broad-spectrum area applied in various fields of research even in air transport. It enables to acquire new knowledge effectively without incurring large financial and personnel costs and without the necessary risk in case of incorrect parameterization of the application directly into the running process during operation.

2. Problem Description and Data Collection

Our primary goal was to optimize the passengers ground handling system at Fryderik Chopin Airport in Warsaw on Wizzair flights based on available operational information. Based on the findings, it was necessary to define the key parameters and factors that affect the process of passengers ground handling. Subsequently, to create a process-based simulation model and to perform an initial simulation of the process problem state, based on which we could optimize the entire process of the ground handling system in order to improve management and operation efficiency of the process. In order to meet these objectives, it was necessary to define the mathematical model of the queuing system in addition to the efficient processing of input data and to use the simulation of the given processes for the needs of subsequent optimization. Fryderik Chopin Airport in Warsaw is Poland's largest airport and is one of the 50 busiest airports in Europe (Fig. 1). In 2017, it was the most frequented airport from the group of V4 countries. The number of passengers handled and the fact that all types of transport operate at this airport as well as the fact that it offers short-haul domestic and international short-haul networking and subsequent long-distance and intercontinental flights and low-cost flights, make this airport a suitable object for research and optimization of the passengers and baggage ground handling process using the queueing thery.

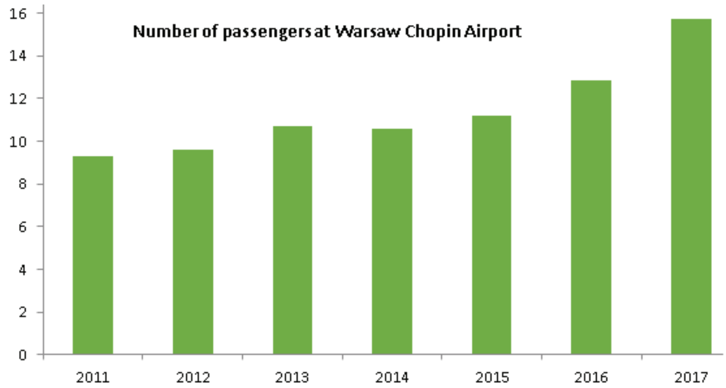

Fig. 1 Development of the Number of Passengers at Fryderyk Chopin Airport in Warsaw (in millions of passengers)

Warsaw Airport has one terminal, which was built after the airport was reconstructed by connecting two original terminals. This terminal is thus composed of two parts, the north and the south one. There are 5 check-in zones throughout the terminal. The southern part of the terminal is the older terminal and has 2 check-in zones (A and B). The more modern, northern part of the terminal includes check-in zones C, D and E. Thanks to this terminal, Warsaw Airport's capacity is up to 25 million passengers. Chopin Airport operates approximately 300 flights a day and over 50 airlines operate at this airport. The most widespread airline operating at this airport is LOT Polish Airlines, which holds up to 40% of all traffic. The second most widespread company at the airport is the low cost Wizzair, whose traffic is rapidly increasing [3].

To optimize the passengers and baggage ground handling process, it was necessary to obtain data and information on the handling process of passengers at the airport as well as data on the number of passengers per line. For the collection of this data we have chosen low-cost flights of Wizzair. There are 9 check-in desks opened for the Wizzair´s flights. The following tables (Table) show the numbers of passengers for the selected lines of this company on normal business days and weekends.

Table

Number of passengers on Wizzair flights on a weekday and a weekend day

Time Odletu	Flight Number	Destination	PAX
5:55	W6 1321	Birmingham	229
6:00	W6 1301	Londýn	236
6:05	W6 1431	Bergamo	224
6:05	W6 1339	Bari	155
6:25	W6 2468	Budapešť	177
6:50	W6 1505	Göteborg	178
7:15	W6 1591	Agadir	138
8:55	W6 1575	Kutaisi	174
9:55	W6 1501	Štokholm	177

Time odletu	Flight Number	Destination	PAX
5:50	W6 1321	Birmingham	214
5:55	W6 1487	Alicante	176
6:00	W6 1301	Londýn	234
6:05	W6 1431	Bergamo	228
6:05	W6 1339	Bari	154
6:50	W6 1505	Goteborg	177
7:15	W6 1591	Agadir	131
8:55	W6 1575	Kutaisi	178
11:15	W6 1567	Kyjev	175

For the purposes of characterizing the mathematical model we used the busiest hour of these days, ie the time when most flights are handled. In both of the days examined, this is the time between six and seven o'clock in the morning, as shown in Table 1. Additional data that was necessary to determine the accuracy of the simulation was the average time spent by the passenger at the check-in desk, how many passengers really come to the check-in desk, how many people travel with luggage and also how many people are subject for more detailed physical checks. In the case of Wizzair, the average time spent is slightly lower than for other companies, as many passengers travel without luggage. Such passengers then spend little time at check-in or do not appear at the check-in counter and go straight to the security check. The average time per passenger was one minute, with about 50% of the passengers coming to the trip. Similarly, on average 50% of passengers have luggage that they have to register at the trip counter. It is common practice in security control that approximately every other passenger is subject to more detailed physical checks.

3. Simulation Model of the Problem and Simulation

Before the simulation itself, it was necessary to create a simulation model based on the mathematical model of mass operation to optimize the parameters of ground handling of passengers and luggage. By simulation we do not get a direct optimal solution; by simulation we can examine the impact of the decision on the simulation model and give us the possibility of effective decision making. We used Rockwell Arena software from Rockwell Automation, which was developed for simulation in all areas of human activity, to create this simulation model and simulate it. It is used in areas such as the food industry, engineering, aerospace, manufacturing, supply businesses, government and military, retail, healthcare, call centers, logistics, transportation, and customer service. Regardless of the industry, Arena enables companies to solve any business problems in a fast and cost-effective way [4-7].

After finding out all the necessary operational data and limitations, we could proceed to create a simulation model. In its creation, we have maintained the best practices in creating architectures of common two-phase mass-handling models. Since data on security controls and baggage handling may be distorted due to the fact that it is not possible to determine exactly how many lines are devoted to one company flights, the simulation will take place in the ground handling passenger subsystem, assuming that half of all passengers would come to the check-in desk and based on the results of this simulation, we will propose changes to the simulation model of the system if all the passengers arrived at the check-in desk. Nine check-in desks have been entered into the system, which are in operation and service for Wizzair flights. Input data were used to specify how often passengers arrive at the check-in desk and the number of requests, i.e. how many passengers need to come to the check-in desk. The next block addresses the way from the entrance to the check-in desks, and what time it takes passengers to pass from the entrance to the airport check-in desks. The time of handling one passenger is entered in the features of the check – in desks. Next, we defined the time of the way from the check-in desks to the output stage, which is in terms of the system the entry into the security check. The resulting simulation model architecture shows Fig. 2.

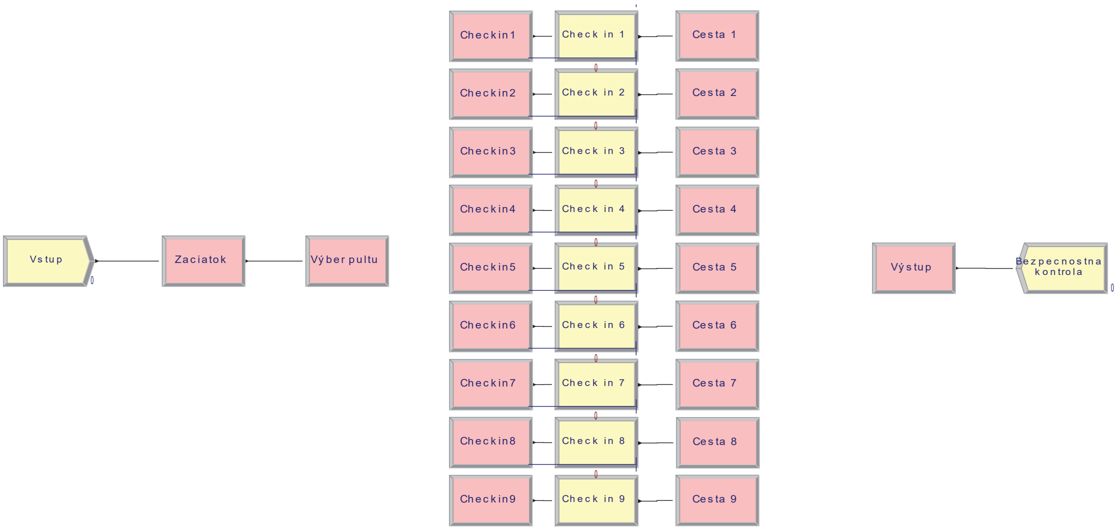

Fig. 2 Passengeres handling model by Rockwell Arena

After assembling the architecture we could proceed directly to the simulation so it was necessary to insert data that we want to work with. Based on the data collected we defined the time of handling one passenger for 1 minute, and the length of the way from the entrance to the check-in desks and from check-in desks to the security control for 2 minutes. This data remained fixed throughout the simulation and did not change. Variable data in our case related to passenger input flow, the difference between the arrival of passengers to the check-in desk and the number of passengers requiring service at the given time. In the first case, we chose about half of the daily peak traffic at Fryderik Chopin Airport on Wizzair flights, in which case passengers arrive at approximately 7.5 second intervals. From the simulation output data, we can read that the average waiting time at the check-in desks ranges from 2 to 3 minutes and the maximum waiting time was generated on the check-in desk number 5, almost up to 10 minutes. The most passengers (59 passengers) in this simulation were handled at the check-in desk number 4 and 6. The simulation results are shown in Figs. 3 and 4.

Waiting Time	Average	Half Width	Minimum Value	Maximum Value
Check in 1.Queue	3.1717	(Insufficient)	0.00	8.2850
Check in 2.Queue	2.7102	(Insufficient)	0.00	7.8287
Check in 3.Queue	2.9126	(Insufficient)	0.00	7.6097
Check in 4.Queue	2.1441	(Insufficient)	0.00	7.4573
Check in 5.Queue	2.4985	(Insufficient)	0.00	9.9292
Check in 6.Queue	2.0095	(Insufficient)	0.00	6.3549
Check in 7.Queue	2.6506	(Insufficient)	0.00	5.8900
Check in 8.Queue	2.2167	(Insufficient)	0.00	6.9307
Check in 9.Queue	2.1897	(Insufficient)	0.00	5.2873

Fig. 3 Waiting times at check-in desks

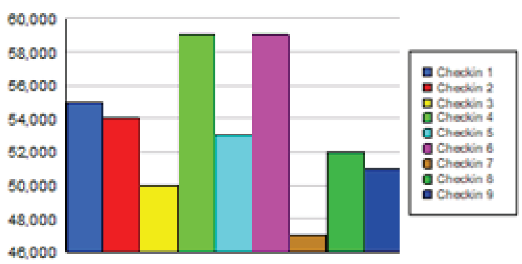

Fig. 4 Number of PAX handled at individual check-in desk

The following simulation was used to determine the maximum number of passengers that can be arrive to the check-in desk so that ground handling of passengers can be carried out smoothly and without delay. With unchanged features from the previous simulation, we found that such a model could accept a total of approximately 600 passengers who would enter the system at 6-second intervals. In practice, this means that approximately 62% of all passengers can arrive at check-in at a daily weekly peak for passenger ground handling service. In this simulation, the average waiting time was again about the same, and the maximum waiting time jumped above 10 minutes in two cases. In this case, the most passengers (78 passengers) were handled at the check-in desk number 4. The simulation results are shown in Figs. 5 and 6.

Waiting Time	Average	Half Width	Minimum Value	Maximum Value
Check in 1.Queue	2.8133	(Insufficient)	0.00	8.3281
Check in 2.Queue	2.4684	(Insufficient)	0.00	7.1720
Check in 3.Queue	2.9082	(Insufficient)	0.00	8.1027
Check in 4.Queue	1.6986	(Insufficient)	0.00	6.8790
Check in 5.Queue	2.5156	(Insufficient)	0.00	10.3377
Check in 6.Queue	2.5803	(Insufficient)	0.00	9.1596
Check in 7.Queue	2.1583	(Insufficient)	0.00	10.0647
Check in 8.Queue	2.7075	(Insufficient)	0.00	5.9611
Check in 9.Queue	2.3137	(Insufficient)	0.00	6.4317

Fig. 5 Waiting times at check-in desks at the largest possible burden

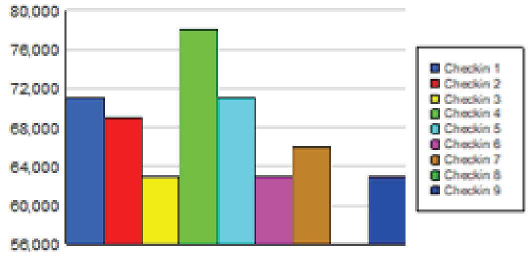

Fig. 6 Number of PAX handled at individual check-in desks at the largest possoble burden

In the situation that all passengers who fly Wizzair's flights at the busiest hour at the airport would have to arrive at the check-in desks, the simulation was carried out with a critical failure due to the overload of the simulated system model. The software has already made a mistake after 179 passengers in such a simulation, due to too few passenger arrivals. In practice, in the process of passengers handling, Wizzair automatically assumes that nearly 40% of passengers will use a different form of check-in service than at the check-in desks. Based on these new experiences, we decided to review and optimize the model in order to ensure that it will work on the assumption that all passengers traveling on a peak day will arrive to the check-in desks. Adding multiple check-in desks as well as increasing the time to handle passengers may appear to be suitable alternatives to changing parameters, which means that the check-in desks would be open earlier for Wizzair flights. It was found by gradual screening and simulation that in order to serve all passengers traveling by Wizzair on a daily peak, the passenger handling process had to be started 30 minutes earlier, thus increasing the arrival time of the requests. At the same time, it is necessary to open three extra desks. The passenger arrival interval was thus 5.6 seconds.

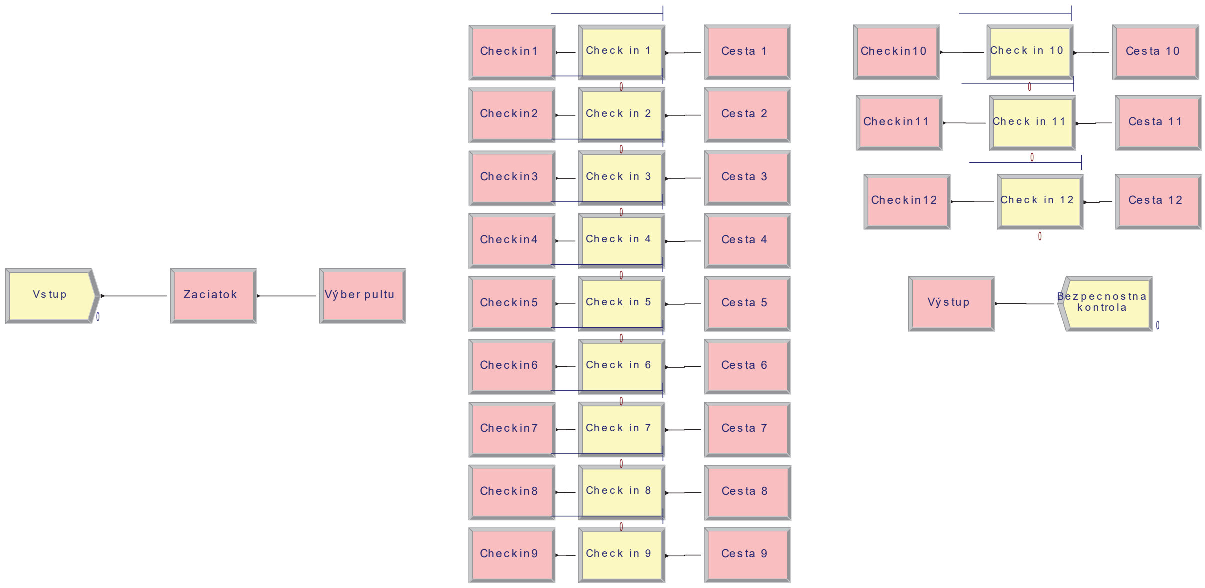

Fig. 7 Optimized passenger handling scheme at Rockwell Arena

After simulating such a model, we could see that the waiting time is considerably higher. The average waiting time is approximately 3.5 seconds, with a maximum waiting time of up to 18 minutes at check-in desk number 7 (Fig. 7). Most passengers have gone through the check-in desk number 9 (a total of 92 passengers). The simulation results are shown in Figs. 8 and 9.

Waiting Time	Average	Half Width	Minimum Value	Maximum Value
Check in 1.Queue	4.2470	(Insufficient)	0.00	9.0540
Check in 10.Queue	3.3077	(Insufficient)	0.00	6.2860
Check in 11.Queue	4.7660	(Insufficient)	0.00	14.3500
Check in 12.Queue	3.4992	(Insufficient)	0.00	10.5834
Check in 2.Queue	3.4459	(Insufficient)	0.00	8.6090
Check in 3.Queue	4.1790	(Insufficient)	0.00	10.6897
Check in 4.Queue	3.8405	(Insufficient)	0.00	14.6380
Check in 5.Queue	3.2700	(Insufficient)	0.00	8.6118
Check in 6.Queue	3.7792	(Insufficient)	0.00	11.3675
Check in 7.Queue	3.0353	(Insufficient)	0.00	18.1639
Check in 8.Queue	2.8801	(Insufficient)	0.00	8.6114
Check in 9.Queue	2.2442	(Insufficient)	0.00	6.8232

Fig. 8 Waiting times at the check-in desks

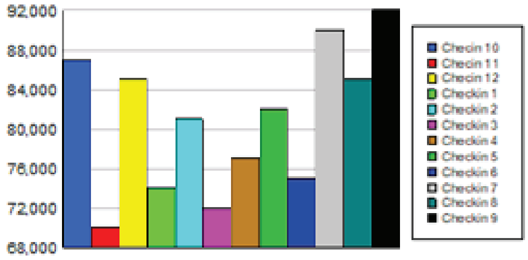

Fig. 9 Waiting times at the check-in desks

4. Conclusion

The facts found during the individual simulations of the Wizzair passenger handling process have substantially altered our vision of the operation of the passenger handling system at Fryderik Chopin Airport in Warsaw during daily and weekend peaks defined by the previous assumptions. In the first model, it has been clearly demonstrated that the process of passengers handling is smooth, provided that not all passengers travel with luggage. Since the airport only opens nine check-in desks for Wizzair flights, we can assume that they have this number of passengers so that the check-in desks are not overloaded and automatically assume other forms of passenger check-in (online check-in, self check-in terminals etc.). By simulation, we found that the highest number of passengers that can arrive to the check-in desks and the system will run smoothly is approximately 600 passengers in one hour. In a simulation attempt, when all passengers at the busiest hour of the airport arrive to the check-in desks, the system will experience congestion and downtime and delays in operation will result in increased handling agent error rates and increased nervousness and discomfort during the passengers handling process of the given flight. It is interesting to note that Wizzair increases the risk of delays by doing so.

Therefore, it was necessary to develop a proposal for optimization changes to the ground handling model if all passengers had to come to the check-in desks. Such a model counts on the fact that passengers on given flights would be able to come to the facility 30 minutes earlier, thereby increasing the theoretical average passenger arrival intervals and relieving the system. At the same time, it would also be necessary to open three more check-in desks. After changing these parameters, we can say that the ground handling system for the busiest traffic at Fryderik Chopin Airport for Wizzair flights is optimized, despite the high waiting times of passengers. In practice, in this simulation, we can also optimize other cases of ground handling at other airports, as the system is the same everywhere, and parameters that change, such as the number of passengers, arrival intervals, or check-in time can be changed quickly and easily.

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