3D Modeling and Simulation of the Check-in Process Using Information Technology

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Abstract — **The use of information technology at the airport facilitates the management of all processes and ensures the highest degree of security. In addition to these information systems, airports may also use information systems that allow pre-test the impact of the expected changes in the activities before their implementation in full operation thereby saving considerable costs if the expected change is inappropriate. This is done by modeling and simulation programs that allow you to create and view any reality and see how the system behaves when the input data is entered. This allows airports to find optimal solutions to optimize airport processes. The article discusses such information technologies to support modeling and simulation of airport with the support of 3D visualization of simulation results.**

The authors examine the available simulation tools and compare them on the basis of available functions useful for modeling and simulating airport processes. And by comparing them, they present a possible optimal information solution. Next, they explore the possibilities of deployment and present a solution for using such an information system for modeling and simulation of the passengers' handling process and displaying the simulation process in a real 3D model of the terminal at the airport in Košice.

Keywords—modeling, simulation, ARENA simulator, 3D, visualization,

I. INTRODUCTION

Increasing demand for air transport causes congestion and delays of various kinds, which are becoming increasingly common in airport operations. Uncertainties associated with these problems make it difficult for airports, airlines and air traffic service providers to manage the air traffic. Therefore, it is highly beneficial to use modeling and simulation technologies to predict such delays by testing the impact of expected changes before they are put into operation, thus saving considerable costs if the foreseen change is inappropriate [6].

The issue of modeling, simulation and 3D visualization of simulation results is a wide-spectrum area applied in various areas of research and in air transport. It enables to acquire new knowledge efficiently without incurring high financial and personnel costs and without the necessary risk in case of incorrect parameterization of the application directly into the sharply running process in operation. One of the market leaders in the process of planning and design of airport processes with many years of experience and numerous references is an independent provider of professional advice in the field of airports and aviation, a German company, Airport Research Center GmbH (ARC).

The ARC company offers a software solution that helps to optimize investments and reduce operating costs and other services in the following areas:

- Airport planning and design - assessment of existing plans, strategic planning, development of land-use plans, optimization of master plans, development of concept studies, functional planning of all airport areas, etc.
- Simulation at airports - a key step in process optimization, also allowing you to understand the interaction and dynamics between different services, processes and passengers.
- Capacity assessment - an important factor in ensuring sufficient capacity or efficient use of provided capacity.
- Aviation market analysis and forecast - essential forecast for the approval process, investment and infrastructure planning;
- Aeronautical and technical studies - to ensure the highest level of safety and to assess or to identify the impact of deviations from airport standards and national regulations;
- data collection at airports [1].

The complexity of problems evaluation, or the large number of variants, does not give the designer or manager the choice of the optimal solution when using conventional tools. Due to the uncertainty of the development and requirements of transport, decision making under time pressure, limited amount of money and unavailability of modern tools, it is difficult to talk about overall system optimization. Computer simulation [5] is a suitable tool for solving such problems.

II. INFORMATION TECHNOLOGY FOR MODELLING AND SIMULATION

There are a large number of modeling and simulation programs available on the market using information technology. Our aim was to find an information solution based on the analysis of available information solutions, that would meet the requirements for modeling and simulation of airport processes. Therefore, in the selection we focused mainly on those that are at least partly oriented to transport and airport processes.

For efficient selection of the most suitable solution it was necessary to analyze the individual parameters with regard to the usability for airport processes. We have defined five criteria for selecting the optimal solution. The selected information system must fulfill features such as "aviation oriented" and "simulation of airport processes", as such a program will include functions and libraries to simulate the problems of airport processes. Each program must support the analysis of results in the form of graphs or other diagrams and therefore we have chosen the criterion of "support for the analysis of results", because the changes in reality depend on evaluation and decision during the simulation. Furthermore, we focused on supporting 3D visualization of simulation results, as this can be an advantage for better approaching the simulated problem to an impartial observer. We were also interested in the licensing policy of the system manufacturer. Both Free/Open Source and Proprietary licenses can be used.

TABLE I.
THE LIST OF ANALYZED INFORMATION TECHNOLOGIES

	License Type	Aviation Oriented	Simulation of Airport Processes	3D	Support for the Analysis of Results
ARENA Simulator	P	✓	✓	✓	✓
ASCEND	F	×	×	×	✓
CAST Simulation	P	✓	✓	✓	✓
DWSIM	F	×	×	×	✓
Elmer	F	×	×	✓	✓
Enterprise Dynamics	P	✓	✓	✓	✓
FlexSim	P	×	×	✓	✓
GNU Octave	F	×	×	✓	✓
Lanner WITNESS	P	✓	✓	✓	✓
MATLAB	P	×	×	✓	✓
Minsky	F	×	×	×	✓
Mobility Testbed	F	×	×	✓	✓
NetLogo	F	×	×	✓	×
ns (network simulator)	F	×	×	×	✓
OpenSim	F	×	×	✓	×
Simio	P	✓	✓	✓	✓
SimScale	P	✓	×	✓	✓
SimWalk	P	✓	✓	✓	✓

From Table 1 it can be seen that all programs that are Free or Open Source are not suitable for our needs. Neither of them sufficiently met the selection criteria we set. Most programs support modeling and simulation in other areas such as physics, mathematics, chemistry, biology, or computer networks. Only Proprietary licensed programs met our criteria. We found MATLAB, FlexSim and SimScale the least compliant, because although MATLAB already includes Aerospace Toolbox, which is customized for aviation, it was primarily developed to solve math problems and Aerospace Toolbox is just a technical-oriented, not aviation-oriented add-on. FlexSim does not have enough functions and libraries to simulate airport processes and is primarily production-oriented. SimScale is primarily designed to simulate physical problems. We identified Enterprise Dynamics, Simio and Lanner WITNESS as compliant. Programs in this category are usable in a variety of areas and their features are also partially adapted to solve problems of airport processes. CAST Simulation and SimWalk have been identified as the most suitable programs because these programs were primarily developed to simulate problems of airport processes and therefore contain various libraries and features for these problems. For example, the CAST Simulation program consists of three parts, CAST Terminal, CAST Aircraft and CAST Vehicle, which are independent of each other but can also be combined. CAST Terminal is designed to solve problems in terminals such as passenger movement, check-in, passport control and others. CAST Aircraft solves problems with aircraft movement and CAST Vehicle solves problems with vehicles and ground handling such as fueling, buses, cargo and luggage transport and others. SimWalk is also applicable in other areas, but with its primary purpose of simulating the flow of crowds (passengers), it is also useful in aviation. With features, modules, and versions customized for airports such as SimWalk Transport, SimWalk Airport, and more, it is used by airports to analyze terminal layout solutions. This program can be used to plan terminal capacity enhancement or evacuation planning, as at present, terminals and public transport buildings are highly challengeable targets for various threats. After comparing and evaluating the programs, we would therefore recommend CAST Simulation programs, which are most adapted to various airport processes, to model and simulate airport process problems. There are also programs in the category - compliant, where it is possible to simulate any airport processes, but there may be problems sometimes and the simulation model will not reflect the full reality. A special case is the Arena Simulator program, which is a universal modeling and simulation system, its quality and supporting technologies are fully usable for modeling and simulation of airport processes. Also its licensing policy is more suitable than CAST, so we have decided to use this system despite some disadvantages [4].

III. MODELING AND SIMULATION OF THE CHECK-IN PROCESS

A. Problem

We have verified the correct choice of solution on the model of the airport passenger process, namely the check-in phase. To create it, it was necessary to analyze the whole airport process, where we examined from what parts the process is formed, what are the input parameters, how they can be measured and how they can be influenced by conditions during the calculation, what variables and constants enter the process during the calculation operations what the result is, and in what units of measurement the result is expressed. The process of passengers handling can be decomposed into simple parts that were important in creating the resulting model. The first part is the arrival of the passenger at the airport, the second part is the decision of the passenger to which class they belong (whether it is a first class passenger, second class or already checked-in passenger) and at which check-in desk he/she can be handled, the third is the decision to which check-in desk to go and wait for the check-in, in the fourth part, after waiting in line, the passengers go to the check-in desk and the last fifth part is the departure of the passenger from the check-in desk and goes to security check. This implies that the input parameters of the model may be the number of check-in desks, the number of check-in staff and the number of departures gates. The influencing condition of the model may be the number of passengers, the throughput of the desks, the time of the passengers' handling and the airline's requirement to initiate the check-in desks.

The model´s search result may be the total capacity of the desks, the time required to handle the passengers of the flight in question, the number of desks required or the number of employees required. Parameters are influenced by the conditions and the given problem that we want to solve and from the desired result that we want to achieve [2].

Based on the analysis of available data, we have chosen that the input parameter will be the number of check-in desks, the influencing condition will be the passenger's handling time of the flight and the searched result will be "the required number of check-in desks". In our case, therefore, the input parameters (check-in desks) will be influenced by the check-in time of the passengers and we need to figure out how many check-in desks are needed to handle all passengers during the check-in time. During computational operations, variables (passenger's check-in time) and constants enter the process. The result will be expressed in the number of check-in desks required to handle all passengers. From the analysis it was possible to create a model of the airport process and this proposal will be later used in the modeling in the selected simulation program.

B. *Proposal of the process model*

In the analysis of the airport process we divided the process into five parts. The first part is the arrival of the passenger at the airport. The second part is the decision on the travel class of the passenger. If it is a first- or second-class passenger, the passenger continues to the third part. In the third part, the passenger decides which check-in desk to go to and if necessary to wait in a row. In the fourth part, the passenger's check-in is carried out and then leaves for a security check. In the case of an already checked-in passenger (the passenger was checked-in before the journey, for example via the Internet), it goes directly to the last fifth part, namely "Passenger departure for security check" [4, 6]. The proposed model will later be created in the Arena Simulator and verified. The solution to the problem will depend on the input data. We retrieved the passenger's check-in times at the check-in desk from the passenger check-in times generator.

C. *Passenger check-in time generator*

One of the input data for the simulation is also the random passenger´s check-in time. We have obtained this data from a programmed, random passenger check-in time generator [3]. In order to generate data, it is necessary to specify the number of passengers to be generated, the variance of the numbers generated, which in our case represents the deviation from the average passenger's check-in time and the average passenger's check-in time. An example of input data for first class passengers is shown in Table 2.

TABLE II.
FIRST CLASS PASSENGERS´ CHECK-IN TIMES

Pax	Num.	Time (s)	Time (min)	Pax	Num.	Time (s)	Time (min)
PAX	1	113	1:53	PAX	11	113	1:53
PAX	2	128	2:08	PAX	12	110	1:50
PAX	3	128	2:08	PAX	13	112	1:52
PAX	4	130	2:10	PAX	14	114	1:54
PAX	5	125	2:05	PAX	15	118	1:58
PAX	6	118	1:58	PAX	16	125	2:05
PAX	7	118	1:58	PAX	17	128	2:08
PAX	8	112	1:52	PAX	18	125	2:05
PAX	9	115	1:55	PAX	19	116	1:56
PAX	10	118	1:58	PAX	20	112	1:52

D. *Simulation model*

The aim of the simulation was to find out the number of check-in desks for the handling process of passengers at a given check-in time. Modeling was also derived from this goal and process analysis. For this simulation we chose Arena Simulator. The created model is shown in Figure 1.

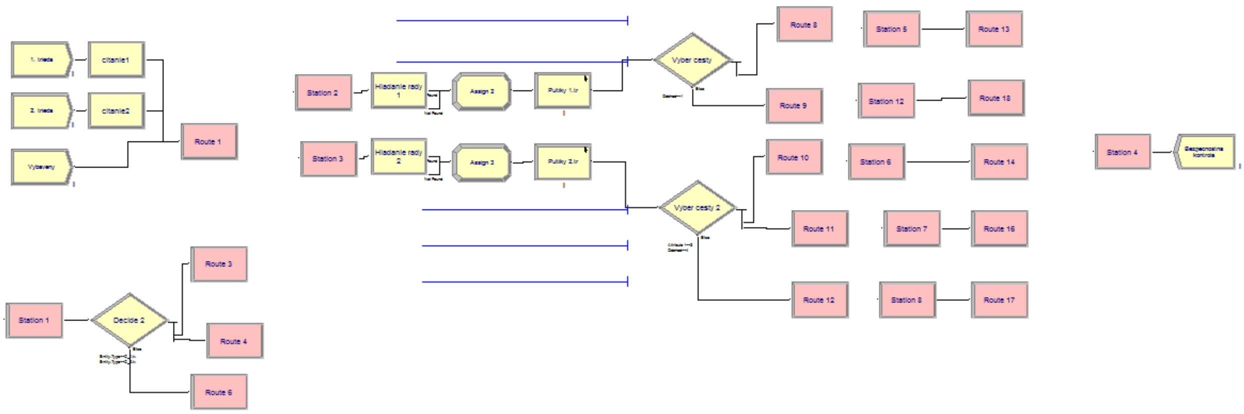

Figure 1. Model of the airport check-in process of passengers

The resulting model was validated by a validation and verification system to eliminate errors. You had to enter the input data before running the simulation. We have set a total simulation time of 90 minutes, which is the usual time for passengers handling process (check-in) before the flight. Since we have defined first and second class passengers and already checked-in passengers in the model, it is necessary to set the input parameters for each model block. In the first class block, 20 passengers are generated, in the second class 100 passengers and in the checked-in block 25. We also had to set the time between arrivals of individual passengers. In the first class we set 20 seconds, in the second class 10 seconds and in the case of already checked-in passengers 1 minute. The blocks 'reading1'and 'reading2' read data from Excel tables, where we previously imported the passengers' check-in times and assigned this data to the individual generated passengers. We have set the number of open check-in desks for the First Class 1 desk and for the Second Class 3 desks. The aim of parameterizing the simulation is to determine whether this number will be sufficient to handle all passengers.

E. 3D visualisation of the simulation

Thanks to the function of the Arena Simulator program to support 3D visualization of simulation results, we imported the created 3D model of check-in desks at the Airport Košice [4].

The resulting simulation then took place in that section. To complement the visualization of the simulation process, we added 3D passenger models that we assigned to entities and resources. The source was in our case a check-in desk, which handled passengers, so we have assigned a 3D model of the woman (Figure 2, first woman from the left) to the 3D model of the check-in desk of the Airport Košice. We assigned a 3D female model (Figure 2, second woman from the left) to the entity that represented a First Class passenger and a 3D model of the man (Figure 2, a man in a red T-shirt) to the Second Class. Passengers who are already checked-in and not participating in the check-in process are shown with a 3D model of a man (Figure 2, a man in a green shirt).

Figure 2. 3D models of entities and resources

IV. DISCUSSION

After assembling and parameterizing the simulation model, it was possible to run the final simulation of passengers´ handling process (check-in) and its continuous display in the 3D model of the check-in area of Košice Airport. The resulting simulation is shown in Figure 3.

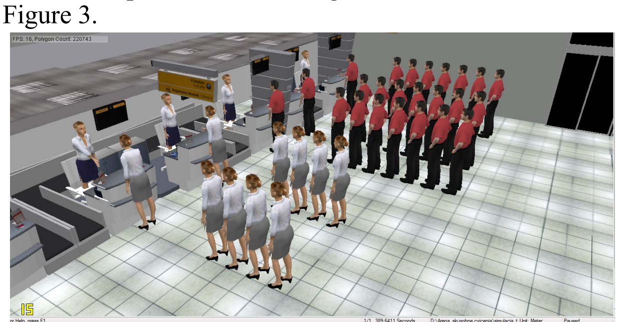

Figure 3. Visualization of simulation by Arena Visual Designer

After the simulation is performed, the program generates a report with the simulation results. From our report, we found that in 90 minutes all passengers were checked-in. In the report (Figure 4), we can find the Minimum Value, Maximum Value, and Average Wait Time, Transfer Time, and Check-in time at the check-in desk (Other Time). All data are in seconds. According to the report, the first-class passenger waited on the in a row for an average of 317.28 seconds (5:17 min), the second-class passengers waited in a row for an average of 1381.56 seconds (23:01 minutes). It took an average of 33 seconds for a first-class passenger to move from the check-in desk to the security control, a second-class passenger for 22.65 seconds, and for an already checked-in passenger who did not come to the check-in desk and just moved from the terminal to the security control an average of 13 seconds. At the check-in desk, first-class passengers stayed an average of 119.90 seconds (1:59 minutes) and second-class passengers 122.61 seconds (2:02 minutes).

Wait Time	Average	Half Width	Minimum Value	Maximum Value
C_1.tr.	317.28	(Insufficient)	0.00	679.32
C_2.tr.	1381.56	(Insufficient)	0.00	2904.74
checked	0.00	(Insufficient)	0.00	0.00

Transfer Time	Average	Half Width	Minimum Value	Maximum Value
C_1.tr.	33.2500	(Insufficient)	31.0000	36.0000
C_2.tr.	22.6500	(Insufficient)	21.0000	26.0000
checked	13.0000	(Insufficient)	13.0000	13.0000

Other Time	Average	Half Width	Minimum Value	Maximum Value
C_1.tr.	119.90	(Insufficient)	115.00	125.00
C_2.tr.	122.61	(Insufficient)	113.00	125.00
checked	0.00	(Insufficient)	0.00	0.00

Total Time	Average	Half Width	Minimum Value	Maximum Value
C_1.tr.	470.43	(Insufficient)	150.00	827.32
C_2.tr.	1526.82	(Insufficient)	140.00	3049.74
checked	13.0000	(Insufficient)	13.0000	13.0000

Figure 4. The Report Generated after the Simulation Process – Times

A very important information for us was the usage of check-in desks. From the report (Figure 5), we know that the first class check-in desk 'desk1(pult1)' was used by ten passengers and ‘desk2(pult2)' was also used by ten passengers. The second class check-in desk 'pult3' was used by thirty-four passengers and the desk 'pult4' and 'pult5' were used by thirty-three passengers. For us, this means that if we wanted to optimize this process, we could close one of the 'pult1' or 'pult2' and only one of them would be used.

Resource

Usage

Total Number Seized	Value
pult1	10.0000
pult2	10.0000
pult3	34.0000
pult4	33.0000
pult5	33.0000

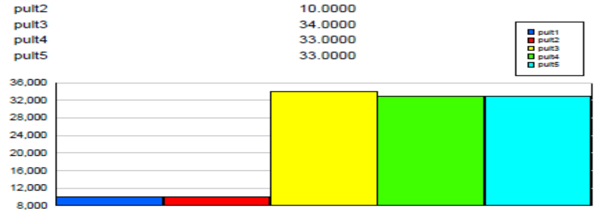

Figure 5. Usage of check-in desks

For a better evaluation of the results it is possible to see a graphical representation of the simulation results. Figure 5 shows the graphs for "Number of passengers in rows" and "Occupancy of check-in desks". At the same time, the data from these graphs was shown in the table, because the graphs with the table change according to the current state of the simulation.

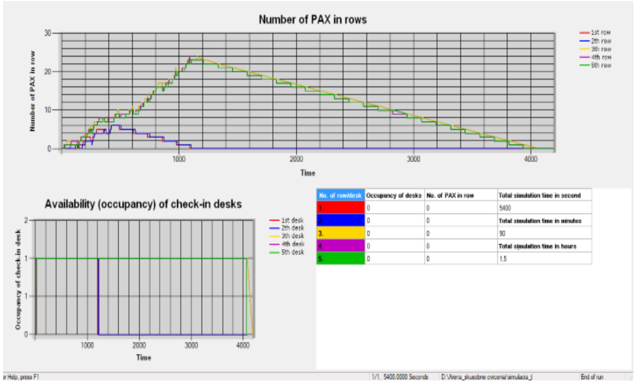

Figure 6. Usage of check-in desks

According to the chart "Occupancy of the check-in desks" (see Figure 6.) we can see the most visible use of the desks. Obviously, the first-class check-in desks are used up to 1200 seconds (20 minutes) and therefore it is more efficient to leave only one desk open (working). In case we prefer to choose higher comfort for first class passengers we can leave both check-in desks open. The second-class check-in counters are used almost until the end of the simulation. At about 4100 seconds (68:20 minutes), all second-class passengers are no longer handled. The total check-in time is 5400 seconds (90 minutes) and we can see that after all second-class passengers are handled (checked-in), check-in desks will remain idle for 1300 seconds (21:40 minutes). However, this time can be considered as a reserve for "unexpected events" that may occur during the handling (various delays). It is also possible to consider closing one check-in desk, but in our case passengers would not be able to check-in for the flight. With a simple recalculation, we find that if the number of passengers (100 PAX), the throughput of the desks Pr = 1PAX / min. (considering two running (open) check-in desks and the passenger's check-in takes 2 minutes), cyclic interval CI = 10 min. and check-in time Dob.Vyb. = 90 min., the cyclic interval throughput is PrCI = 10 PAX (PrCI = CI / Pr), which means that every 10 minutes the airport will handle 10 passengers. So we need 100 minutes to handle all passengers. However, we have to handle passengers in 90 minutes. Therefore, the most ideal solution is to open three check-in desks for second-class passengers and to maintain time for unexpected delays.

From the report and graphs, we found that the number of check-in desks open meets the current conditions. We can only consider closing one desk for first-class passengers, but this could reduce them for greater comfort.

V. Conclusion

Airports have a large number of information technologies at their disposal to support the modeling, analysis and optimization of airport processes. Some programs are directly developed to simulate airport processes and these are the most suitable for airports. In addition, programs that have not been directly developed for airport processes, but usually include functions or libraries that allow it, can also be used. We proved this fact by modeling and simulating the airport process in Arena Simulator, even though this program is not directly designed to simulate airport processes, but also focusing on simulating other processes, it was able to model, simulate and then display the results of 3D simulation of passengers´ handling process at the Airport in Košice.

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