Airport Operation Staff Training Utilizing Simulations of the Defined Airport Processes

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ABSTRACT

In this article the authors present a model of an integrated symbiotic education system of airport operations staff training based on an effective exchange of information for realizing the training between the airport staff and information systems simulating the defined airport process for which the cooperating staff is trained. The most important activity for smooth and effective airport operations is resolving capacity issues of the airport. Insufficient capacity may slow down traffic, cause delays, what can be the reason to increase costs and to reduce quality of services and passenger satisfaction. Generators creating flight schedules and referring the number of received aircrafts and passengers after check-in process may resolve this problem, where it is necessary to set up correct methods of operational and system analysis. This simulation makes it possible to see if airport capacity is sufficient to manage full aircrafts under regulated conditions. Our article further deals with computer model design and 3D simulation of airport processes and finally summarizes its strengths and weaknesses with main focus on airport operations processes. Appropriate use of simulation in aviation sector can reduce overall time and costs.

Keywords: Education System, Airport Staff, Airport Process, Simulation, 3D model, Check-in Process.

1. INTRODUCTION

The present high level of technologies is offering a wide spectrum of possibilities for implementing technological elements and structures into the process of educating aviation personnel. An important element of the mentioned process of aviation education is in using simulation technology in an area where the absence of direct contact with real systems, in the course of education, can be, to certain extent, replaced with a simulated interface. Under the conditions of strict supervision over the costs, it is necessary to verify the potentials of the planned systems and find innovatory and succesful solutions. The demand for changes in technology or organizational processes, however, is bringing about certain risks. Establishing limit to the risks envolved are assisted by predictive technology and methods of simulation, which enable modeling the operational environment and simulation of the consequences of various decisions made. The task of simulation consists in evaluating the real possibilities available for supporting important strategic incentives. Above all, simulation is a process of experimenting with a model either for the pourpose of understanding the behaviour of the system or evaluating the various strategies of the system operation. The complex nature of the education methodology, when one of the conditions is replaced by simulation is, in terms of perception, substantially more effective as handing over information by way of standard projection. The reason behind is based on the skills of natural memory of a human being, where it is taken for a fact that quantifically the major part of absorbed information is made up by those at which the logical relation have been understood.

2. INTEGRATED SYMBIOTIC SYSTEM SUPPORTING EDUCATION OF THE AVIATION STAFF

Education in complex systems of aviation represents a set of principles, methods and tools arranged in a way so as to warrant the results. Quality of education is presented by an efficient level of teaching students, as future aviation porfessionals and aviation staff, willing to advance in qualification. Even though the actually applied methods and procedures have been verified in practice and experiences, the development in information technology is creating new educational potential for improving the practical methods hitherto employed at various levels of aviation education. For us to find a perfect solution to education and approach to real processes taking place in complex technical systems, it is necessary to enrich the educational pack of aviation personnel with a set of simulation tools and computer-based methods of teaching termed as Computer Based Training, as a need of merging classical methods of teaching with those new and progressive ways of education. With the help of these tools, it will be necessary to put together functional units, which will bring education in the given profession as close as possible to practice. Education with the help of integrated system is implementing theory into real processes with the help of information techologies, which create a synthetic environment using computer technology, imparting the entire process a higher momentum. Involved in the process are information technologies functioning on the basis of simulations of mathematical descriptions of the situations. The synthetic environment is perceived by us as an artificially developed intelligent environment, which with the help of computers provides potentials for performing various operations without making use of real technology. There are lots of advantages to the synthetic environment (for example the removal of doubling the subject in the process of teaching etc.), which are exponentiated by the economic effect. The fundamental scheme of the process mentioned can be seen in Fig. 1. Effectiveness of such education is unambiguously based on using dynamic models and simulation techologies.

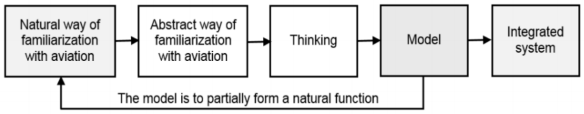

Fig. 1 Integrated system of education in aviation

Methods of education with the help of Computer Based Training Technologies enable realizaton of such integrated systems as a basis fo education, which, by way of direct relation, is interconnecting laboratory environment with real airport processes. Such concept is termed as a symbiotic environment, which, in the light of aviation staff preparation, enables providing educational processes lead by a lecturer. His or her task is to carry out professionally and instrumentally the process of teaching controlled by the „symbiosis" of students´ abilities as regards the combination of intelligent demonstrations of aircraft characteristics along with its airborne information systems.

3. MODELING AND SIMULATION OF AIRPORT PROCESSES

In airport operation we are encountering issues focused on eliminating problems in the process, finding ways of innovating and improving it, or the entire airport as a system. There are many answers to those problems, however, the issue remains in the verification of the righteousness of our decisions and their impact on the behaviour of the entire system of the airport operation after having implemented the changes. One of the possib ilities is in simulating the airport process (AP). Simulation is a technology providing a correct and a relatively rapid answer to question „What if...?" (e.g. What if the capacity of the terminal building is raised?).
Modeling and simulation of the AP clears away the defficiencies of the analytical methods, however, it is simultaneously more demanding in terms of time and preparation of the input data. Reasons of making use of simulations at airports, appart from the fact the realization of the projects at airport operation is too costly or impossible without using analytical methods of computation, can be in that the overall realization of the project regarding airport operation is impossible to carry out (there is no system so far), realization of the porject right at the airport operation is too dangerous or there is no need for forecasting the future events.

The realization of the simulation is conditioned by developing a simulation model. Then the realization of the simulation is in presenting an experiment with the model. Simulation enables extending the scope of the scrutiny also to specific types of models, in which the random variables are taken into consideration, the value of which is the result of a specific type of probability distribution. As a matter of course, simulation can be realized, with deterministic models particullary in cases, where the computation of the results of the experiment (finding) with the given model would be too complicated. Presentation of the reality using models and subsequently realizing the experiment by way of computer simulation is not a simple job. A scientists appart from the branch having studied has to be in command of methods and procedures associated with mathematics, statistics and information techology. Neither of them can warrant that simulation will be capable of properly capturing the rather complex interwinement of relations of the reality investigated.

Systems of simulation offer a variety of outputs, which in certain terms are subjected to statistical processing. On the basis of the results obtained, one is capable of making further decisions, which will be tested by simulation, continuously experimenting with the system with the purpose of achieving optimal of results. Simulation is considered efficient in case, when the changes brought about cost less money and yield the most. A precisely built model of the AP with a properly defined structure is the basic condition of a correctly performed simulation. The process of developing a model involves extensive use of almost all the general methods of science.

4. NETWORK ANALYSIS UNDER THE CONDITIONS OF AIRPORT OPERATION AND CAPACITY MODELING

For the purpose of modeling airport operation, it is suitable to make use of the network diagrams for more transparent and better understanding of the principle underlying the handling processes. Graphical illustrations of the handling processes enable grasping more exactly the flow and conditionality of handling the individual activities in each of the handling processes with respect to the criteria, i.e. safety, time and performance.

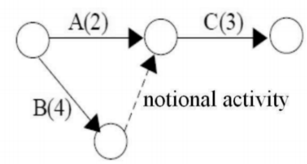

Fig. 1 Network diagram

An advantage to the network diagram is the relative ease of adaptation to various modifications made to the process. It consists in the fact that there is no need to re-draw the entire graph if contingent changes are made. Changes in safety checks or in durations while performing passenger handling processes are sufficiently recognized by modifying the diagram adding the so-called cyclic nodes.

Description of initial and final states (peaks)
Each graph describing the way of handling starts with the initial point, the so-called start or input. As the proces will continue going on towards further peaks (nodes, states), each start (input) into the process is therefore marked with ***S0*** (initial status). By way of a properly chosen markings of peaks (states) from S1 to SN indicating states where exactly the travellers will be found in the process of airport passenger handling. The process terminates with the so called final peak marked as K0 (Final state). It is a status the passenger has to or should get into, on condition that he or she is acting properly throughout the entire process of handling, until passing through all the stages designed for the concrete handling process. The time flow and contents of operations at each state from S1 till SN and operations starting with C0 and ending with C_M will always be different, whereas states of S0 and K0 will be constant. Concretely, the status S0 as a starting peak will express the state - „I have bought a ticket, but I have not arrived at the airport" and the final point of K0 will denote the status – „I am sitting in the aircraft after having been handled successfully at the airport" or it has been an unsuccessful check-in.

Description of the problem state

However, there can be a specific when the passenger is denied the flight for various reasons e.g. in case of irregularities in air services (overbooking, technical failure of the aircraft, weather) or unreasonable conduct of the passenger, when the security staff of the customs and visa departments will need enough time to for repeated control and verification of the passenger. Another case may occur when a prohibited or dangerous item not allowed to air transport is found during the baggage handling. In that case the baggage having passed over a multi-stage detection control and evaluated as „impure", cannot be taken on board and transported by air. Subsequently the passenger is again „connected" with his or her baggage either in via a public address call or directly by the security staff. All that is taking place in exclusive areas airports are required to have if to comply with the regulations. All the reasons mentioned and those further are mostly causes for the passenger to be denied of boarding the aircraft. It can happen in any stage of the passenger handling process All these states can be jointly marked as P0 (problem state), of which only in extraordinary cases is there a way back, i.e. the passenger is allowed to step further in the passenger handling process.

Evaluation of the handling processes by network diagrams

The basis for the evaluation and treatment of the airport handling processes by means of detwork diagrams is subdividing the entire process of passenger and baggage handling into partial operations. Such approach is aimed to express their specific characteristics, with emphasis on requirements for security, operation and capacity so that the process of simulation could cover all of them and the model involve each operation affecting the result measured. Every way of passenger handling can be assigned several states (peaks) and operations (edges). States marked with „S" and operations marked with „C", will be those interconnecting these states. States in the handling process represent completion of several mutually coherent operations, i. e. activities the passenger have gone through in the process. It is important to identify several essential states the pasenger will be involved in during the steps of the passenger handling process such as check-in, handing over the hold baggage and its screening, passport control (visa control), customs control, security check of each passanger, the hand baggage and medical check. Appart from these essential states we can distinguish further ones such as additional security, passing baggage into the „drop off" counter and states when using the self-service check-in system. Operations, unlike the states mentioned, will be over and above. When evaluating these operations we have to take into consideration mainly the time of duration, or the time when they started and ended. It is to mean that the individual operations or services will have to be appreciated in terms of time, whereas the state need not have this data as attributes.

Passenger handling at the check-in counters at the airport terminal buildings

This way of handling is rated among the classical forms of the process, so far being the most frequent ways of handling, which can be seen on most airports and threreby applied into the modeling of airport operation for the purpose of simulation. Let us mark this state as S1A.

Description of the states and operations present at traditional forms of passenger handling:

- ***S0*** (initial state) – supposing that the passenger has bought a ticket and has not arrived at the airport yet.
- **C1** – operation involving the transfer of the passenger to the airport, in view of the great variety of time transfers used by passengers, the duration of this operation will bear no importance to solving this problem.
- ***S1A*** – a state when the passenger arrives at the airport and joins the que for the check-in, state S1A also involves a situation when the passenger makes use of the check-in in the terminal building of the airport at fixed chek-in counters, attended by trained staff of the airline company.
- ***C2*** – representing a passenger check-in, which, depending on the number of counter and the type of air transportation, can take several seconds or minutes to complete.
- ***S2*** – a state when the passenger has successfully completed the check-in by making use of the counters at public or sterile part of the airport.
- ***C3*** – includes handling the passenger´s hold baggage, which is weighed and properly marked by the handling staff then loaded onto moving belts that form part of the handling counter set up. As a follow-up, in the baggage control system, the baggage is subjected to detection control and finaly, if considered „pure", it is loaded into the right aircraft.
- ***S3*** – state, when the passenger has successfully completed check-in and handed over his or her hold baggage at the chek-in cunter.
- ***C4 and C5*** – involve operations of the passport control, if the passenger is travelling without hold baggage, then in via edge C4 he is transferred into state S4, when the passenger is travelling with hold baggage, in via operation C5 and is transferred from state S3 into state S4, at flights within the Schengen area passport control can be bypassed.
- ***S4*** – in this state the passenger has completed registration for the flight, check-in, registering and handing over his or her hold baggage plus passport control, into this state a passenger is transferred in via operation C4 or C5, and this state will form the basis for two further operations marked as C9 and C10.
- ***C9 and 10*** – the passenger is arriving at the security chceck in via operation C9 and also to detection control of his or her hand baggage by way of operation C10, performed in parallel, consequently they are presented alongside in the diagram and in the same direction, duration of detection and security controls can be affected by several factors, e.g. summer or winter season as well as the number of detection devices available at the airport.
- ***C6*** – stands for customs control and proceeds from status S4, used when the passenger is flying to a country outside of the Schengen area or the traveller has been chosen randomly by the airline staff, if the passenger is not exciting any suspicion and his or her baggage is not declared impure, such a check will take only several seconds, and a greater problem might come when additional checks are required, e.g. packing out the entire contents of the baggage and calling in the security components.
- ***S5*** – state of completing check-in, registering the baggage for flight, passport and customs control to be subsequently followed by operations C8 and C7, which are identical to operations C9 and C10.
- ***C8 and C7*** – are identical to operations C9 and C10.
- ***S6*** – when in this state, the passenger has already completed check-in, handing over the hold baggage for flight, passport or even customs control as well as detection and screening of the hand baggage, at the same time this status is the one of admitting the passenger into the sterile zone, where he or she is waiting for the departure and expecting to be involved

into a number of operatios – C11, C12, C13, C14, C15, C16, C17. Using or not using them in the passenger handling process depends on the conditions established by the given airport.

- ***C11*** – should no further additional controls of the passengers by the airport as covered by edge C11, he or she may continuously proceed into the aircraft.
- ***C12*** – in some countries, prior to entering the sterile zone, the passenger can be subjected to medical check performed by the airport staff using special equipment to detect various illnesses, the passenger may also be asked to be subjected to medical check on a basis of random choice, or if it is considered inveitable by the momentary situation in the given country.
- ***C11*** – the passenger is allowed to board the aircraft after entering the sterile zone.
- ***S7*** – status of the passenger, after having passed all the previous parts of the handling process along with the medical check and in state S7 there may come several cases forming part of states C13, C14 and C15. If the suspicion on illness of the passenger proves negative, by way of operation C13 he or she is transferred back to the sterile zone, if the a suspicion regarding passenger illness is negative and he or she has successfully passed the medical check, by way of operation C14 the passenger is transferred to the aircraft, however a quite different situation may arise in case when the medical check proves positive. Consequently, the passenger is prohibited to board the plane and by subsequently employing operation C15 he or she is transferred to the final point marked as P0.
- ***C16*** – is a random check of the passenger, hand baggage, travel documents etc.
- ***S8*** – status expressing a set of operations performed ranging from S1 to S8.
- ***C17*** – the traveller is getting aobard of the aircraft in via operation C17 .
- C18 – if there was as serious porblem and the passenger was denied boarding the aircraft, in via edge C18 he or she has to be transferred into state P0.
- K0 – final point representing a state, into which every traveller is trying to enter in the shortest time possible and without any problems.

The network diagram (see Fig. 2) is illustrating the traditional way of passenger handling at the check-in counters.

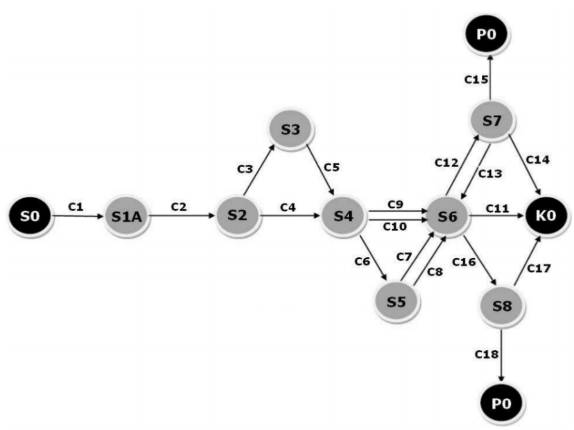

Fig. 2 Network diagram of passenger handling at check-in counters

5. QUEUING SYSTEMS APPLIED TO SIMULATION EXPERIMENTS

Investigating objects applying models of queuing is often aimed to measure the mutual relations between the basic indicators characterising the quality and effectiveness of the queuing system and finding the optimal mode of operation with respect to the chosen criterion. By optimizing the mode of operation can operation of the queuing system one can substantially achieve the possibility of forming queues or reducing the overall losses due to waiting. In every model, it is necessary to define the queue, what is understood by arrival (arriving/departing passengers or aircraft) and the service of handling. The interval between arrivals is describing the input flow of requirements. The time of handling the airplanes, at the aircraft handling area, as well as those of the passengers and the baggage or cargo will then yield the time of servicing or handling.

The input flow of requirements

This is made up of the group of subjects/objects or other claimants, entering the system wishing to be attended to. The number of requirements can be fininte (closed system) or non-finite (open system). The input flow is characterized particularly by the time interval between the arrivals of the individual demands. If this interval is constant, we speak of a deterministic (regular) flow, if random like than it is termed as a stochastic flow. In general the input flow is stochastic process, as the requirements are arriving in the queuing system most frequently at random moments, i.e. the length of the intervals between the arrivals are values of continuous random variables. Most frequently it involves systems with the Poisson´s input flow , i.e. exponential systems. Complications at the input can be caused by the behaviour of subjetcts/objects, who are deiciding whether enter or not the system based on the length of the queue, speed of services at the airport etc.

Service time

It is the time needed to meet a single requirement. The service time is affected by a number of random factors, so it also can be considered as a random variable. Consequently, it is a mean value of this random variable. Division of the times periods taken of service time is governed by the rule of exponential distribution, too. Similarly, the intensity of service is also a random variable, which in our cases of simulating airport operation is understood as the number of subjects/objects served per unit of time.

Discipline of waiting in a queue

Behaviour in the queue is about the will of subjects/objects to wait in the row, or the rule for selecting a queue, passing from one queue to another etc. By patience, queuing systems are divided into ones without waiting and those involving waiting. First and foremost the subjects/objects are impatient, and if there is no free channel at the time of their arrival, they resign and often leave without being served. At systems with waiting the subject /object enters the system and either he is waiting patiently and leaves the system after having been served or is waiting for a certain period of time and if still unserved, leaves the system. Sometimes the subject/object is assigned various degrees of patience.

There is a mode or order to the queue, wchich can also be specified in the course of the simulating airport operation or its capacity. These rules are requirements taken over by the provider of the service. It is about the way how the service channels (FIFO, LIFO, SIRO) or systems are operated with a single queue of several queues, when for each service channel there is a separate queue. In this case it is allowed to change from one queue to another while waiting. The properly chosen mode by which the queue is operated is an important factor ultimately affecting the operational efficiency of the service system.

Number and arrangement of the service lines (service mode) Service can be provided in one service equipment, then it is a system of simple service, i.e. a single-channel system of handling, or when it is taking place in several homogeneous or inhomogeous service channels, then it is termed as a system of multiple handling or a multi-channel handling. A special case is then the adaptable system, in which the number of places in the handling service can vary, i.e. proportionally to the amount of the coming requirements. Arrangement of channels can be in parallel, when there are several homogeneous lins providing identical services side-by-side, or in series ("one after another"), when the requirement must proceed stepwise through several service channels.

6. PRESENTATION OF THE RESULTS OF SIMULATION IN A 3D SPACE

The process of simulation can be presented either in textual or graphical form. Contained in the textual form are values of the variables presented in the separate windows. The values can be exported into a data file, which can serves as a source of data for the simulation in the virtual space. Using animation applications one can develop a 3D space with all the elements of the simulated airport processes. Each element is assigned values from the data file, with established time of simulation (real, accelerated or slowed down) and the view of the virtual 3D space. After having defined the data and values mentioned, the simulation itself is presented in a graphical form, which is capable of providing a more transparent visualizaton of the process. Currently, with our computer-based simulations, it is not enough to produce only a textual and grpahical output in the form of diagrams, we are transferring focus on making use of 3D tools of visualization to present outputs. In cooperation with the AirportKošice j.s.c., we have suggested a virtual concept of our own defined by 3D models of the runway, handling areas, the check-in process of the airport and its utilization for simulation-based experiments [1].

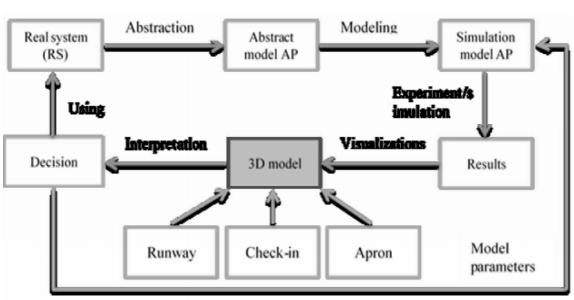

Fig. 3 Process of computer-based simulation

The suggested virtual concept of the computer-assisted system of simulation of the airport processes is based on a classical procedure applicable to the development of simulation-based experiments, which is divided up into the following basic stages [1]:

1) Developing an abstract model - formulating a simplified description of the system investigated, a material not covering all the knowledge on the modeled system, only those relevant to our purposes. The abstract model can take the form e.g. of mathematical equations or a general specification.
2) Creating a simulation model – in essence, it is a program, which can be run and operated based on the results obtained in accordance with the pre-defined initial states, inputs and model parameters.
3) Simulation – the phase during which the simulation–based experiments are performed with the simulation model and and the follow-up analyses of the results.
4) Analysis and interpretation of the results.

This basic model have been extended by a possibility of presenting the results of the experiments directly in a three-dimensional model of the environment, in which the experiment is realized. Based on the experiences acquired, we have found out that this way we can have a better idea on the progress of the experiment, changes in the states of the simulation model and the immediate results depending on the time-intervals of simulation. The ideal status consists in the possibility of making use the concept in real time with the ability to introduce immediate changes to the parameters of the simulation model in the course of the experiment. In order to achieve our goals, it was necessary to develop, with adequate precision, the three-dimensional models of the environments of the processes taking place at the airport. With Airport Košice situated closest to us, it was this environment that we accorded priority treatment to.

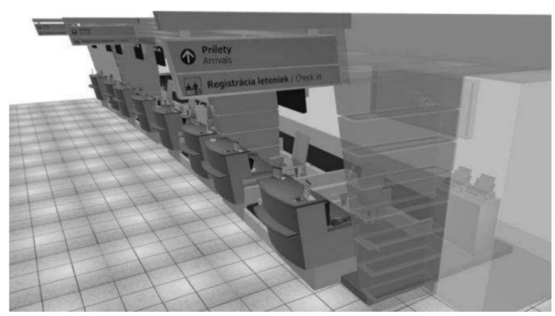

Fig. 4 Plan of the check-in environment

Our aim was to introduce all the information on the individual parts of the Airport Košice into the 3D model developed by us so as to a match it with the modelled reality. Otherwise, our efforts would have not been meaningful at cent per sent and the model could have lost its utility, becoming only a nice graphical work of art. Adherence to the dimensions corresponding to real objects is the basic condition of its further applicability to further simulation-based experiments to be made for verifying various hypotheses while investigating airport porocesses.

7. CONTRIBUTION OF USING COMPUTER-BASED SIMULATION OF AIRPORT PROCESSES

Based on simulation, it is possible to predict values of dependent variables, however, not with absolute precision, as it could be made only in case of employing strictli deterministic models, and only with a certain degree of probability.

Strengths of the computer-based simulation

- Enabling solution of analytically non-solvable problems
- Facilitating solutions of task difficult to solve
- Standardizing some quantitative parameters
- The process of developing the model helps revealing and specifying new realities
- Exptending the potentials for prediction to be made even to field, where it is incorrect to make use of deductive methods, or deterministic models

Weaknesses of computer-based simulation

- In essence, the model represent a certain simplified reality
- Possibilities of failing when simulating extreme events
- Possibilities of manipulation – a certain level of subjectivity is possible
- Method, which is not general

The essence is in choosing the right model when simulating airport processes. The process of simulation involves both simulation performed on a static model assuming only one reaction, whereas applying a dynamic model enables „opting" for one of the multiple of combinantions of reactions. The choice can be influenced by human factor or a controlling logical unit, which, based on the continuous assessment of risks, determines the optimal reaction to the simulated process or state.

Tab. 1 Overview of advantages and disadvantages of the simulation methods

Advantages of the simulation methods	Disadvantages of the simulation methods
Price	Problem of the model validity
Speed	Demandingess on computer performance
Safety	
Availability (often the only available way of investigation)	Inflexibility (when changing paramters, Simulation is often to be repeted)
Flexibility (possibility of modeling Even highly complex systems)	Often high demand on developing simulation models

Within airport porcesses there is a number of areas where computer-based simulation is employed. Typical issues or problems that can be solved in via a simulation project involve investigation as to the type and number of equipment and auxiliaries to to be used, or throughput capacity of the given equipment (Security, Check-in), or the best arrangement of the terminal building, or the optimum of operations or the location of bottlenecks are, etc. Depending on the concrete simulation model of the airport process and on the concrete parameter of simulation, it is possible to introduce into the chosen 3D model other objects, the characteristics or location of which in the model will depend on the values resulting from the simulation, all that even during the process of visualization of the results of the experiments. These values can be both static, dynamic and time-dependent as well. It is possible to state that the resulting complexity of the presented space is the function of the complexity of the simulation model and the demandingness of the user. An example of such resulting visualization of the results obtained from the simulation of airport processes in terms of passenger handling by Check-in to which the passengers are gradually coming in time intervals and are gradually handled is seen further in Fig. 6, down [1].

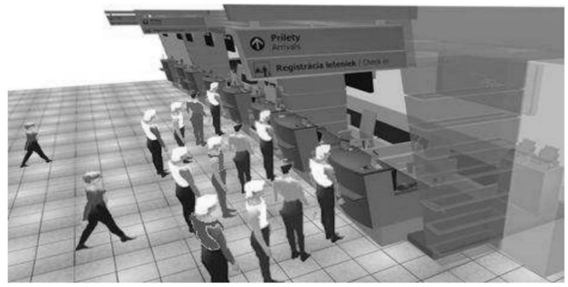

Fig. 6 Visualization of the Check-in experiment results

7. CONCLUSIONS

Scientific methods are devices of any scientific work and without them it would be impossible to obtain true, exact, mutually related (structured) and systematic knowing of the reality, which are the fundamental requirements imposed onto science. In the process of developing the structure of the airport processes model, almost all the generally known scientific methods are used. Of equal importance are attributes such as perfect knowledge of the systems investigated, paritcularly the mutual relations among the entities, state variables and the systems as well. A precisely built model of an airport proces with a properly defined structure is the basic condition for the simulation to be performed correctly. However, one should not forget the fact that simulation is efficient in case when the changes brought about are at a minimum cost while yielding as much as possible. The need to improve the quality of aviation education requires transition towards new ways and skills while making use of progressive technology in education directly affecting safety of air transportation. Having analysed the possibilities provided by modern technology-based tools of education, we have developed a symbiotic concept of education for airport staff making use of 3D dynamic models of the airport processes with the possibility of their back coupling to real processes made available by practice. The purpose of the suggested concept consists in the efficient symbiosis of interpretation of the knowledge in the field of airport processes and the posssibility of acquiring practical knowledge on airoport systems and their functionality under the available conditions.

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