

## OPTIMIZING PROCESS OF CHECK-IN AND SECURITY CHECK AT AIRPORT TERMINALS

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*Abstract: The paper deals with possibilities of optimizing the process of check-in and security check at airport terminals using simulation program. Proposed model is based on real parameters and simulated in the environment of the program Tecnomatix Plant Simulation. This program simulates the process of check-in and security check. Queuing theory will be used for simulation. Principally it means queuing customers, i.e. accumulation of requests, in front of a service centre. Limiting criteria for optimization include operating conditions of airport terminals, financial means connected with personnel resources, legal standards related to safety in air transport and level of service indicators. The aim of the paper is to create a model, which analyses the passenger flow processes at the airport terminal and could be used for evaluating potential changes of the check-in and security check system at airport terminals.*

*Keywords: simulation model, security check, passengers, airport terminals, queuing theory, transport optimization, predict behaviour*

### INTRODUCTION

In air transport, as well as in all kinds transport, there have been tendencies to minimize the time spent on the way. Modern air planes reach such speeds that further increase is nowadays not necessary. Critical point is represented by passenger check-in which is very time-demanding and which represents substantial increase of the total transfer time compared to competitive high-speed railway transport.

The Paper deals with possibilities of optimizing the process of check-in and security check at airport terminals using simulation program. Proposed model is based on real parameters simulated in the environment of the program Tecnomatix Plant Simulation (educational licence), the product of Siemens company. In this program the initial solution is simulated as well as proposed changes in check-in and security check, followed by their evaluation. Queuing theory will be used for simulation of the situations. Principally it means queuing customers, i.e. accumulation of request, in front of a service centre. Limiting criteria for optimization include operating conditions of airport terminals, financial means connected with personnel resources, legal standards related to safety in air transport and level of service indicators.

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## **1. SIMULATION AS AN INSTRUMENT FOR EXAMINING PROPERTIES OF QUEUING SYSTEM**

Simulation of random behaviour system and experimenting with a model create a basic concept of simulation. (1) Therefore it is possible to predict behaviour of systems when internal and external factors change and find such output values of the model which meet the pre-determined requests. Output values of such a solution are then applicable for real system.

Simulation is a useful tool which enables testing possible changes of the system without the need to pilot such changes in vivo. Simulations are used mainly for dynamic complicated systems where it would be extremely difficult or impossible to use analytical methods and time, finance and organization demanding to carry out the changes in real world. The principle of simulation lies in replacing real system by its simulator and comprehensive evaluation of experiments on the principle 'what if'. Results are acquired from or based on observing. As the simulation conditions are given, the results are suboptimal. (2)

The more complicated the system is, the more beneficial computer modelling is compared to analytical methods. On the other hand, the disadvantages lie in difficult interpretation of results of experiments, time or hardware complexity when creating images of real systems or necessary expert training. If the extent of the problem analysis allows the use of analytic model, it is preferable to use it. Simulation software is better for evaluating several alternatives than for searching optimal solution for sets with high (or infinite) numbers of elements.

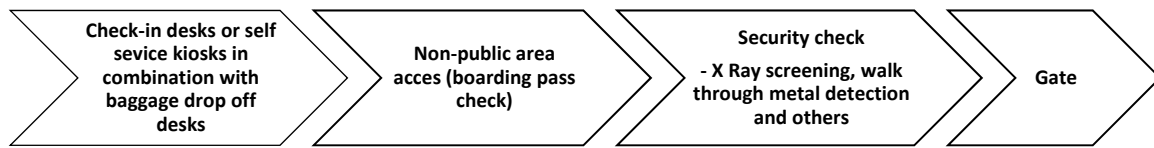
Tecnomatix Plant Simulation is the product of Siemens PLM Software. (3) Product line Tecnomatix is a portfolio of digital manufacturing software solutions for cost reduction and productivity improvement. Following information comes from Tecnomatix: Plant Simulation is a software tool for simulating, optimizing and controlling production, planning and logistic systems. Its environment allows creating dynamic computer models to recognize properties and behaviour of real (functional or planned) processes.

This interactive software enables object-oriented, hierarchical modelling using inheritance of properties. The software allows users to experiment and graphical, analytical and statistical evaluation without disrupting the system. It saves time and money so investment risks are reduced by timely corrective actions. It offers wide range of modules for analysis, such as Gantt Charts, Sankey Diagram, Bottleneck analyser, Statistic analyser or Experiment Manager. It has open architecture with multiple standard interfaces supporting library and object management. Parameterization of objects is easy but it allows advanced surface modelling. Programming language is SimTalk (similar to C++). The software uses random number generation, genetic algorithm, and mathematical formulation for automatic optimization of system parameters.

## **2. SYSTEM OF CHECK-IN AND SECURITY CHECK AT THE AIRPORTS**

Air transport is characteristic for its different check-in process compared to other types of transport. This is based on international character of air transport. Air transport is subject to international regulations which have to be unconditionally observed. (4)

International airports are divided into public zone and non-public area. Security Restricted Area (after security check) belongs to the non-public area. As the security check is necessary and the airports are divided into mentioned parts, the check-in procedure is more demanding (time, organization). (5)



Source: Authors

Fig. 1 - Detailed diagram of passengers' passing through airport terminal (flies to Schengen area)

Passengers enter the public zone of the airport: check-in, air ticket issue and baggage handover. Baggage is inaccessible to the passenger during the flight because it goes in aircraft cargo hold, usually in the same plane as the passenger.

Check-in process is followed by security check and boarding pass check to prevent unauthorised access into the non-public area. In this point the size of hand luggage is at many cases checked according to guidelines of airlines. Each airline has different conditions for hand luggage accepting. The size is checked usually with the frame, as the figure 2 shows. Passport and customs control is applicable before the security check for passengers travelling out of Schengen territory.



Source: <http://www.thinktankphoto.com>

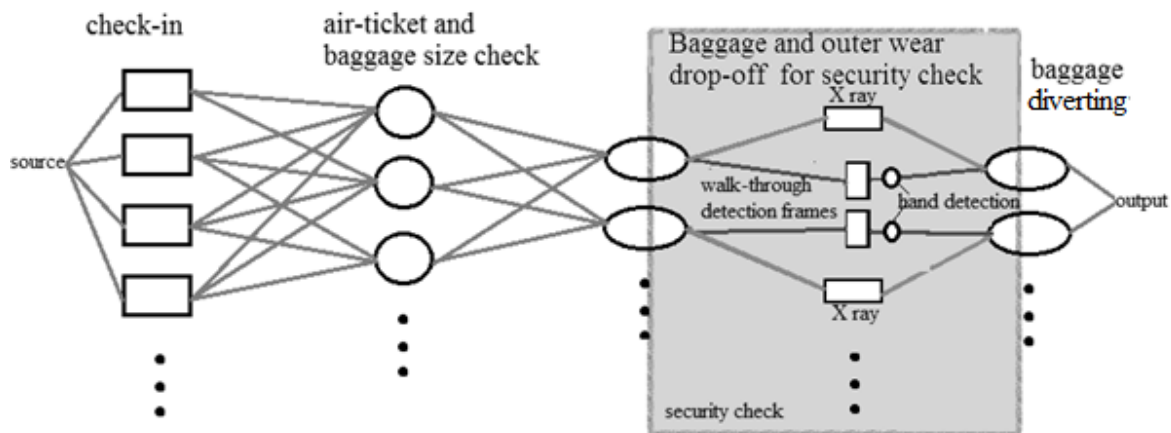
Fig. 2 – Hand luggage size check

Each passenger must be submitted to the security check in the extent specified by above mentioned regulations. The most frequent means of security check are x-ray inspection of baggage, metal detector frame or hand-held metal detector and hand search. After the security check passenger waits in the Security Restricted Area for the instruction to proceed to the gate and board the plane. The whole system is described in details in figure 1.

From the queuing theory point of view, it is the system where passengers' arrivals create a random process. Passengers arrive at the airport according to a certain plan, with random variations. The system consists of three linked service centres: check-in desk, air-ticket and baggage size check and security check. Airports have several linked service centres of the same type (certain number of check-in desks, x-rays, ...). Processing time can be characterized by random variables; passengers are served independently within service centres. (6) (7)

### 3. AIRPORT CHECK-IN AND SECURITY CHECK AS A FLOW NETWORK

In graph theory, a flow network (also known as transportation network) is represented by graph. Abstraction can be used to describe check-in in a simplified fashion as a transport network showed in figure 3 with airport neighbourhood as a source and output leading to the Security Restricted Area.



Source: Authors

Fig. 3 - Check-in system and Security Check as a flow network

Elements of the system are passengers and their hand baggage. As regards their outer wear and other accessories, they are checked in the same way as hand baggage. In the system they are viewed as a part of the element 'hand baggage'. There are properties of elements: a passenger can be a man or a woman, alarm can set off or not as they pass through the metal detector. These properties are attributes of element 'passenger'.

Elements move in batches with the exception of Security Check subsystem (element 'passenger' + element 'hand luggage' or individually (element 'passenger')). For the subsystem Security Check, it is necessary to define that the elements move there independently, on different routes. Before they leave the system, they join to the same batches which entered the system. Baggage (green marked in the subsystem – figure 3) moves on a fixed route and its motion is automatic, which means that the passenger has to respect the route of the baggage and cannot change it. The route of the passenger is marked blue in figure 3. Baggage is screened by X-ray, passengers go through detection frames. Network consists of service centres - check-in desks, self-service kiosks, hand baggage check points (size, security, and handover), x-ray, metal detector and hand baggage diverting. Sometimes queues are inevitable in front of them.

### 4. PASSENGER FLOW IN THE AIRPORT TERMINAL MODEL

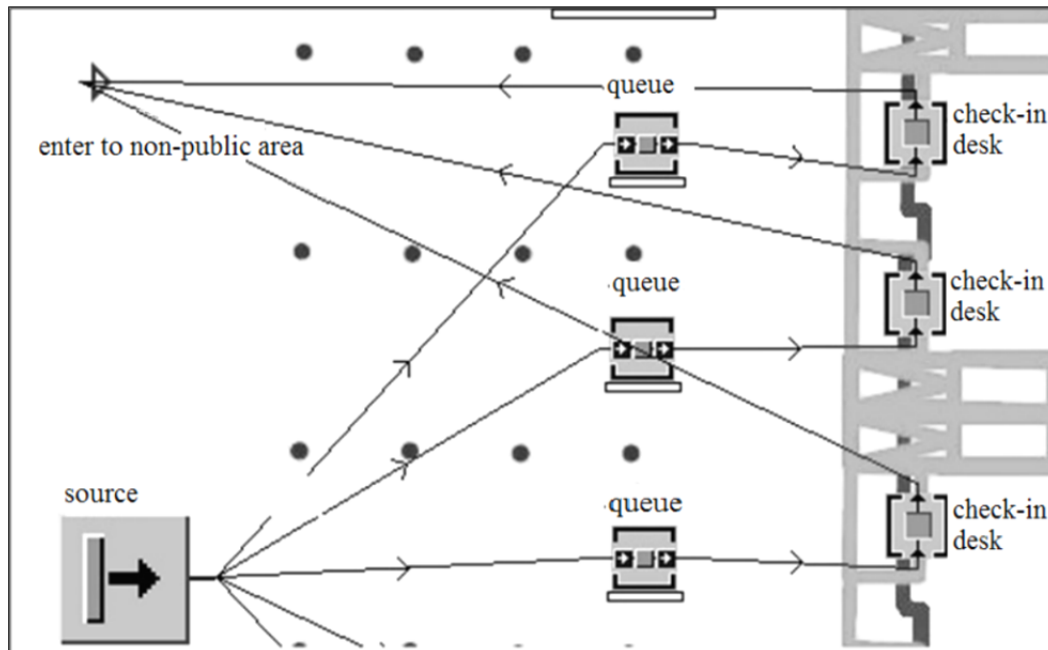
Based on a real data from measurements in the Terminal 2 at Vaclav Havel Airport Prague during November 2012 the model was created. Using this model, the analysis of the passengers flow processes could be made. Basic presumption for model creation is forbidden queue jumping of passengers in the system. This happens in reality but for this model it was eliminated. In real life the passengers often gather to go through together, e.g. families travelling with children do this almost always this way. Although this model does not take into account this fact, when analysing the lengths of processes (to set up a model) the above mentioned phenomenon was considered and lengths were calculated to individual passenger's elements.

Tecnomatix Plant Simulation is originally intended to simulate production systems and processes and optimize material flow, resource utilization and logistics. It was necessary and also challenging to modify program architecture to build simulation model for airport process corresponding to real check-in system and security check. The program, thanks to its general characteristics and variability, is better applicable.

#### 4.1. Creating of model

Model is a closed, dynamic system. On the basis of this layout, the model of the whole system was created. Confidence interval of the model is 95 %. The model should show maximum 5 % difference compared to reality. (8)

Check-in part is directly linked to the source of elements entering the network: 60 check-in desks. Passengers proceed to the desks designated for relevant flight (or airline). Number of passengers in queues in front of check-in or security check is monitored for following modifications of check-in. Figure 4 graphically shows check-in system and links between the sources, queues before the check-in desks (equal for every desk in this phase of the model).

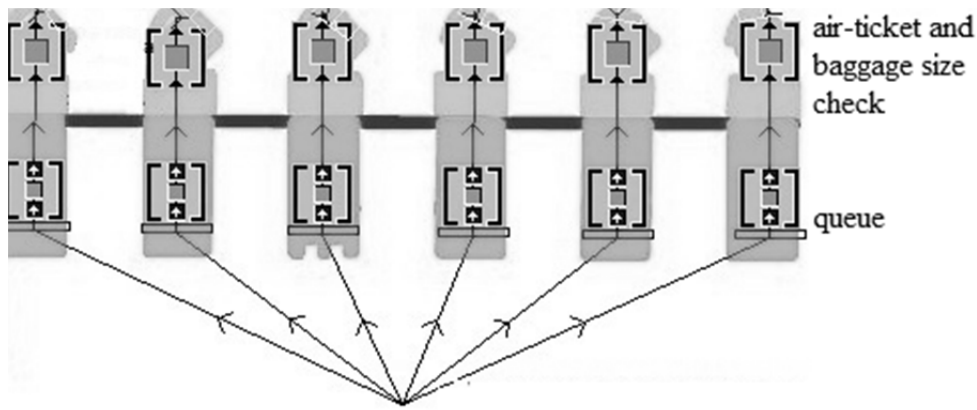


Source: Authors in Tecnomatix Plant Simulation environment

Fig. 4 - Check-in diagram

Passenger comes from the source, which represents the initial access to the check-in system. Then he waits in the queue for check-in desk, if there is no queue (or when he is the first one), the very check-in is performed. After that he leaves the check-in desk and continues to the non-public area.

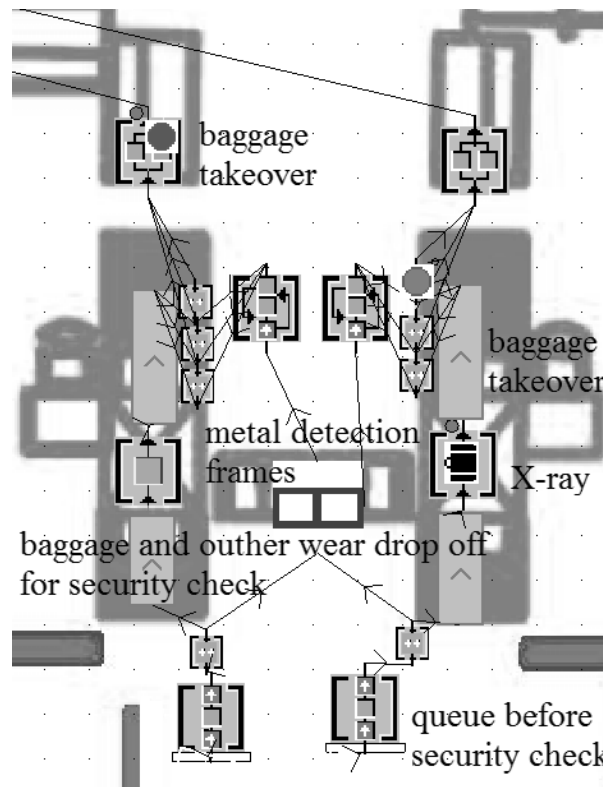
Following part, linked to check-in, is checking boarding passes and hand baggage size. There are 6 checkpoints, with possible queue in front of them as it is displayed including links in figure 5 parallel processes and queues with unlimited capacity.



Source: Authors in Tecnomatix Plant Simulation environment

Fig. 5 - Diagram of baggage and air-ticket check

After this process the passengers gather, depending on their arrival, into one queue (tape demarcation), coordinating the flow of passengers to the security check. As regards security check, this is the most complicated part of the model. The diagram with individual links is presented in figure 6.



Source: Authors in Tecnomatix Plant Simulation environment

Fig. 6 - Security check diagram

In the system, there are 6 pairs of parallel x-rays. After the desks for baggage diverting (baggage takeover) the links lead to the final exit. In real, there is one more X-ray, which is used only for business class. Their check-in proceeds fluently, they are not included into this model.

Passengers come to the security check from the above mentioned one queue and they logically select the service centre with the shortest queue. The cases different from the above described situation are omitted from the model. The queue before the security service centres is linked to drop off desks. Passengers with baggage are viewed as sets, passengers

themselves as parts of sets. Particular attribute - first come first served - is assigned to the set (so as to assign passengers their own baggage), using the algorithm created in the SimTalk program the syntax of which is based on C++ language.

#### **4.2. Input data for model building**

Basic presumption for creating system model is, understanding the system elements. Data entry accuracy is a very sensitive part of simulation which can considerably influence the difference between the model and real world system.

In this case it is always a very complicated issue. For airport processes, the processing time of individual operations is the crucial part for airport operations. However, processing time changes due to external conditions. Particularly in case of security check, the interpretation of data is very complicated. There are numerous influences which often affect their behaviour and decisions. An example of different length of security check time is a passenger who is used to travelling by air who automatically goes through the check compared to a passenger less adaptable, travelling by plane rarely or even for the first time. Further aspect represents waiting in queues which implicitly influences the behaviour of passengers during the security checks in a negative way. The queue behind the passenger can slightly speed up the process.

It is possible to notice that the passengers spend less time going through the security check if there is no queue behind them (in case they are not under time pressure because of forthcoming Scheduled Time of Departure). It is the psychological effect; they do not feel that they have to hurry up. Of course, the security check could not be speeded by the passengers, but in some cases their behaviour could slow down their passing through the security check. Besides that, characteristic behaviour of some nationalities can be observed as well.

Average numbers of passengers arriving for check-in were observed and converted. An average number of 148 passengers per flight was considered. At the time 120 min before STD there are about 23 passengers, at the time 105 min before STD about 24 passengers, about 32 passengers arrive 75 min before STD, on average 44 passengers one hour before STD and 25 passengers 45min before STD. These values cannot be considered a principle, each flight is significantly different: however, they are applicable for the purpose of statistics. (9) (10)

#### **4.3. Model calibration and validation**

Calibration, or, in other words, setting parameters is crucial importance, though of a high risk for model creating. Models are adjusted to the real world system as much as possible. Theory says that all the data used for simulation should remain authentic, without changes. In practice it is considered to be necessary to calibrate the model and adjust the data to reach the most accurate simulation of the real world system.

Program STATISTICA was used to analyse data acquired at the airport terminal and the procedure times were distributed according to their characteristics. Table 1 contains individual processes and statistical functions determining processing time delay.

Tab. 1 - Processing times

Process	Statistic distribution	Parameters		
		A	B	$\gamma$
Standard check-in	Lognormal	4,058	0,4525	-
Check-in (self-service kiosks)	Gamma	25,453	4,4525	-
Baggage size and air ticket check	Gamma	2,3904	0,2575	-
Baggage and outer wear drop-off for security check	Gamma	14,3766	2,2917	-
X-ray screening	Exponential	-	-	0,0464
Metal detector	Lognormal	3,31332	0,2955	-
Baggage and wear diverting	Gamma	25,6701	2,1815	-

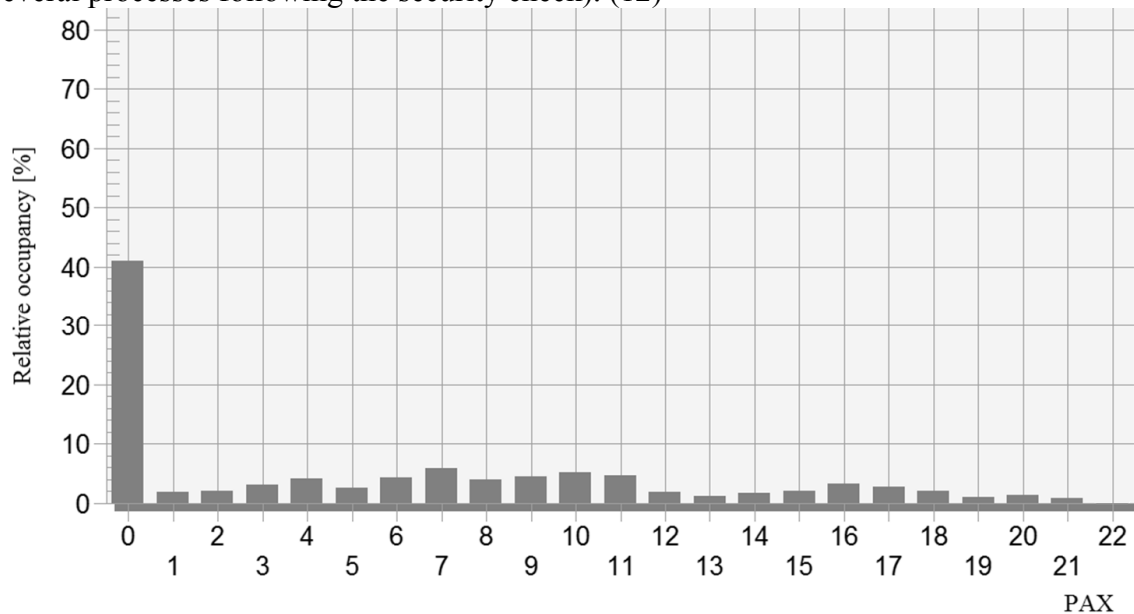
Source: Authors using STATISTICA analysis software

#### 4.4. Detected characteristics of the system

System constructions allowed defining relations between individual processes followed by simulation of the operation in the time of simulation between 9:30 to 14:30. In the same period the measurements of processing time were performed. Detected system throughput was 589 passengers per hour. The proportion of time spent in queues to the total time of system throughput is 24%. Maximum number of passengers before check-in is 21. In the queues at the boarding pass check there are up to four passengers. However the situation differs before the security check. Figure 7 shows the number of passengers waiting in the queue. Maximum length of the queue is 25 passengers. (11)

It is necessary to mention, that these numbers could not be considered as general. The output values are determined with input conditions. The maximal throughput is certainly higher; the mentioned number is decreased by the off-peak hours.

Such huge queues before the security check are undesirable and complicate using airline or airport services making it unpleasant, can reduce LOS (Level of Service – service level defined in IATA) and dynamic capacity of the terminal. Inputs into the check-in process cannot be influenced by the airport; they are individual passengers’ decisions. Process input - queue before the security check depends on check in outputs (which can be influenced by several processes following the security check). (12)

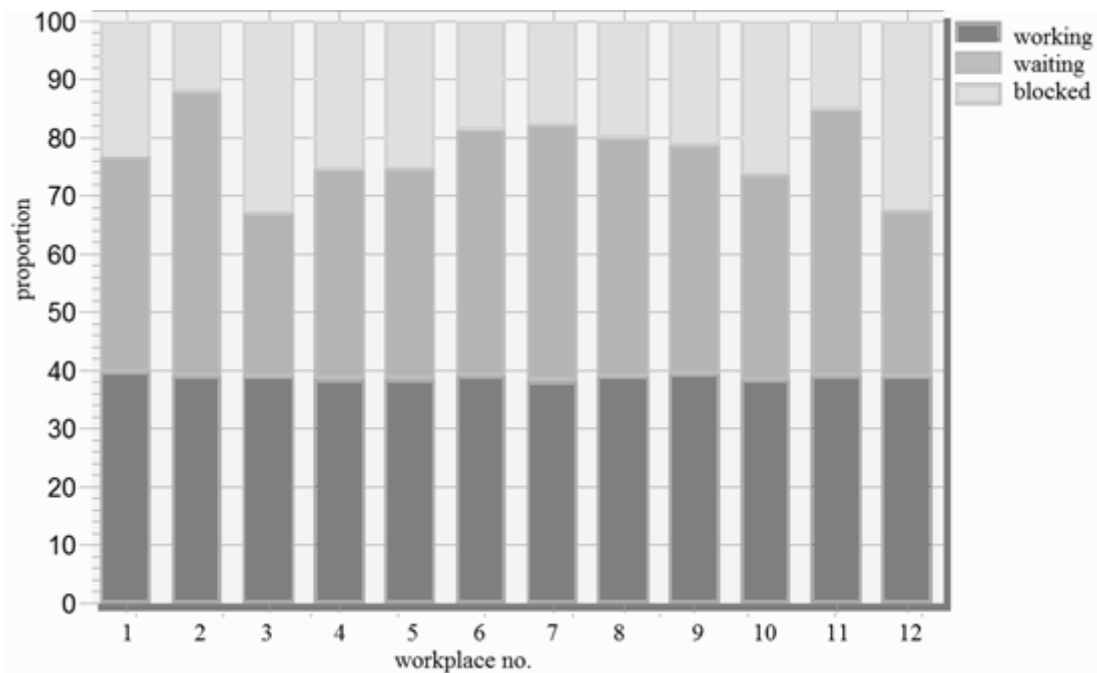


Source: Authors in Tecnomatix Plant Simulation environment

Fig. 7 – An average number of passengers in queues before security check – bar chart



As regards the part of the model simulating baggage drop off before x-ray screening, process blocking can be observed. In practice it means that after the passenger dropped off the items to containers, he cannot proceed to the walk through metal detector because the queue before the security check is out of capacity; or when the passenger walked through the metal detector, but his baggage is blocked on x-ray conveyor belts carrying items through x-ray screening. The queue size before the metal detector increases. Figure 8 shows the proportion of blocked drop off desks and passengers waiting in queues.



Source: Authors in STATISTICA software

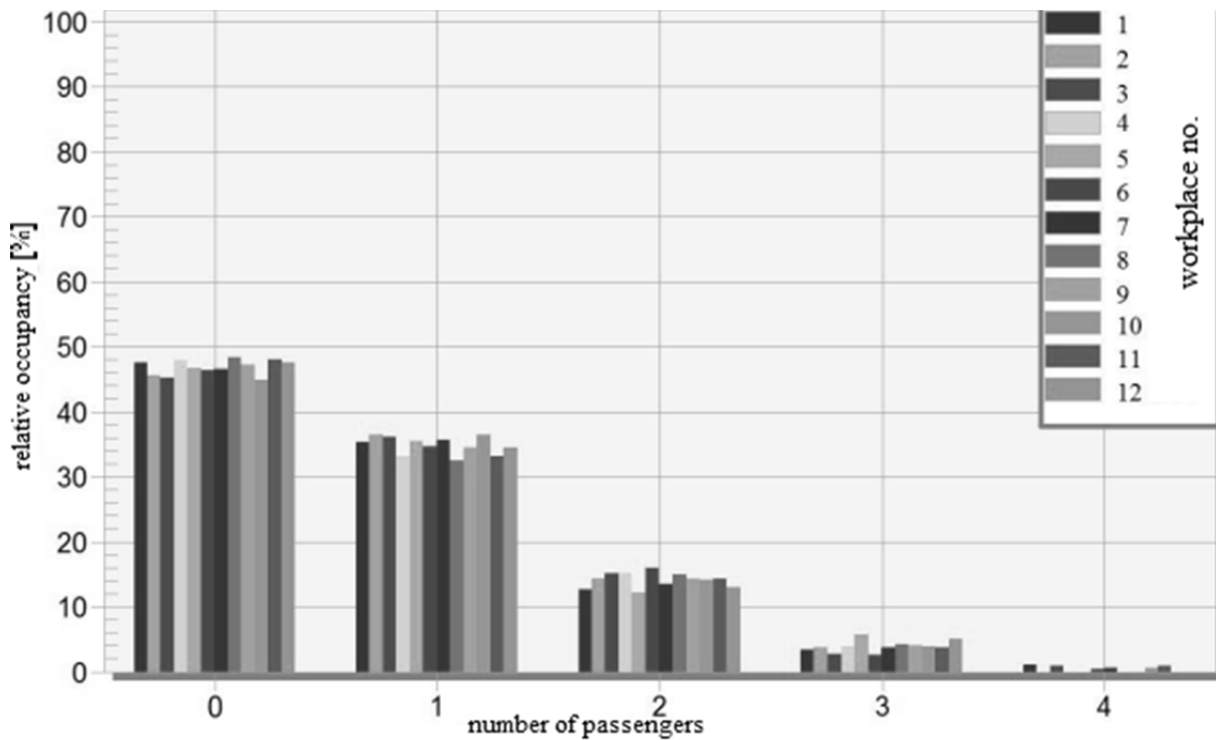
Fig. 8 - X-ray screening utilization

X-ray screening proceeds differently. The x-ray machine is either scanning the items or waiting for them. Security check is not blocked by any other following process. From this fact it is possible to assume that situations with baggage waiting for the passenger on the conveyor belt behind x-ray machine for the passenger do not occur.

Statistics indicate about 2 % of accumulation before the desk for diverting baggage (at the point when the passenger is going to divert his baggage). This happens because the capacity of these desks is low and the diverting process is time demanding. Figure 9 shows occupancy of desks for diverting baggage.

Considering the precedence and sequence analysis (parts of system analysis), it is possible to come to the conclusion that people gather at the baggage diverting point (in real world and during simulation) because this process is time consuming, they have to wait for baggage x-ray screening. This seems to be one of the critical points of the system.

Based on the analysis we detected drawbacks of the whole system lying in the process of baggage drop off for x-ray screening, x-ray screening itself and baggage diverting after walking through the metal detector. The longest queues are formed before or after these processes.



Source: Authors in STATISTICA software

Fig. 9 - Number of passengers waiting before desks for diverting baggage after security check

## 5. CONCLUSION

This functional model was created and analysed in the extent of available data necessary for the model calibration. Calibration and validation of the model was carried out within the presentation of the paper using data from further measurements (November 2012). Analysis of multiple data will contribute to model accuracy.

Created model shows less than 5 % difference compared to reality, so that it respect the confidence interval, which is 95 %. This model creates a usable measure for evaluation of changes in check-in and security check organization.

Simulating the airport terminal operations with proposed changes, differences in behaviour of the system will be observable. Respecting basic limiting conditions, the optimal changes will be evaluated. Data analysis shows problematic nature of the baggage diverting process after x-ray screening when the passenger walked through the metal detector as well as the preparing for security check. Authors propose a measure for improving operation smoothness. It could be increasing capacity of desks for baggage diverting (or for preparing), e.g. their enlarging. Another proposed option could be effective use of self-check-in counters.

Model is usable also for another analysis in the future, because the input data could be easily changed. It is also possible to change model structure, so that it could be used also for evaluating of passenger flow processes in another airport terminal.

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