RIGA AIRPORT BAGGAGE HANDLING SYSTEM SIMULATION

Mihails Savrasovs,
Alexander Medvedev,
Elena Sincova
Transport and Telecommunication Institute
1 Lomonosov Street, Riga, Latvia
E-mail: mms@tsi.lv

KEYWORDS

Baggage handling system simulation, passenger flow forecast, development scenario estimation.

ABSTRACT

The aim of this paper is to describe the example of simulation modelling approach usage for the analysis of Riga airport baggage handling systems (BHS) work. At the first base simulation model was created using ExtendSim software. This model was based on the real passengers' measurements and documents surveys. Further, different scenarios of BHS development were implemented. Different characteristics of BHS were estimated for the use of the developed model. Conclusions and recommendations are based on the results of the investigation.

INTRODUCTION

During last years air transport becomes more and more popular as a means of traveling. Few facts concerns us about that. The number of passengers in 2007 reached 650 million peoples. The turnover of air transport is 260 billions per year. The air transport network is 15 millions kilometers and includes 10000 airports all over the world.

Air transport branch includes two components. They themselves are airports them self and air companies. Each sector has its own goals and business politics, but they are connected. Grow of demand on air transport has big influence on the airports and air companies. ICAO and ACI made the forecast for 2010-2017. This forecast asserts that the markets of passengers will growth by 4% -4.5% per year. The Airbus Corporation gives the forecast by 5%-5.3% level. The factors which influence the passengers grow could be enumerated: population concentration, society incomes growth and the state of industry. Also the same situation is with the airports. According to ACI data in 2006 4.4 millions of passengers were served by airports (Central Statistical Bureau of Latvia 2007). It is higher by 4.8% comparing with previous the year. Also the number of the processed cargo is 85.6 millions tons.

One of the main principal differences from the other transport is that some part of the luggage is travelling separately from passengers and presents another material flow. And at the same time each item of the luggage requires registration, security control and delivery to airplane. It leads to the problem of the luggage serving process organization and control. Also the same process must be executed, when airplane arrives to the destination point.

Since Latvia entered the EU in 2004 the international air companies and Latvian national air company AirBaltic got new opportunities in business development. The huge number of air companies and routes lead to the tariffs decreasing, that also leads to the growing of passengers' number. In 2008 the number of passengers reached the mark of 2 millions. According to IATA forecast growth of passengers until 2011 year will be on the level of 12% (the highest in the world).This leads to the problem of the luggage processing in airports.

The main goal of this paper is to describe the experience of using simulation as a tool of the analysis baggage handling system (BHS) in the airport of Riga (Latvia).

MODELLING OBJECT DESCRIPTION AND PROBLEM FORMULATION

There are 4 airports in Latvia: International Riga airport, airport Liepaja, airport Valmiera and airport Daugavpils. In this paper only the baggage handling system of international Riga airport will be discussed. So the BHS could be described as follows. There are 31 check-ins, which are connected with two parallel conveyers. The staff register baggage and put it on the conveyer's belt. Conveyer's belt delivers the luggage to the security zone, where it is checked using x-ray on the restricted items. During this check the security officer takes the decision: if the luggage needs to be checked more strictly or not. If the decision is negative (no additional check is required) the luggage goes to the 1st flow to the equipment area, where the luggage is sorted and loaded to different flights. If decision of the security officer is positive, the luggage

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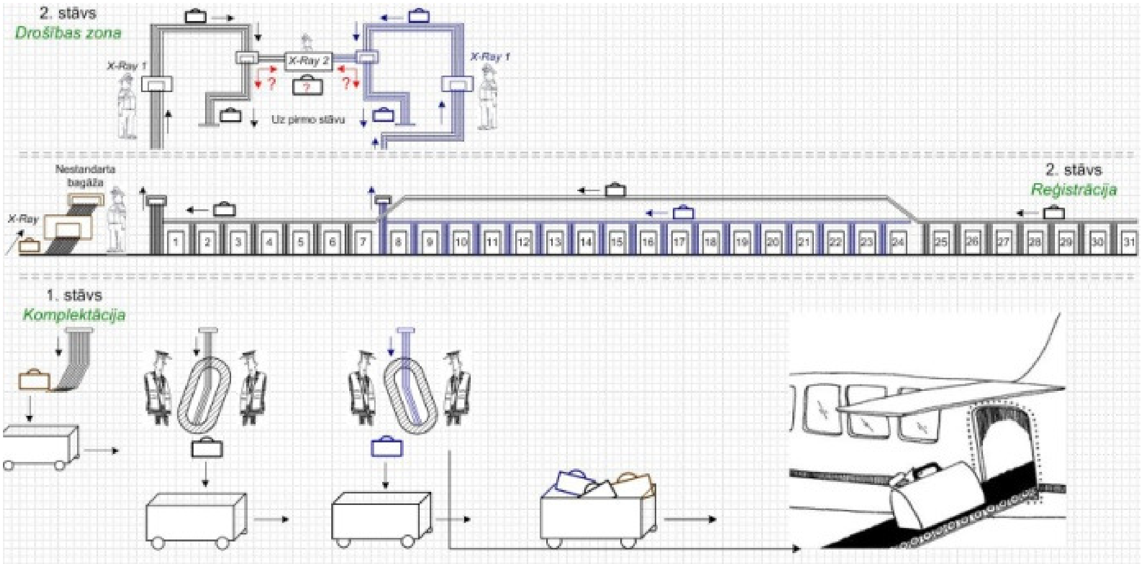
should take additional security control using x-ray and it is required the inspection of the officer. If everything is in order, the luggage will be sent to the 1st flow. The scheme and used conceptual model of BHS of Riga is presented in figure 1 and figure 2 accordingly.

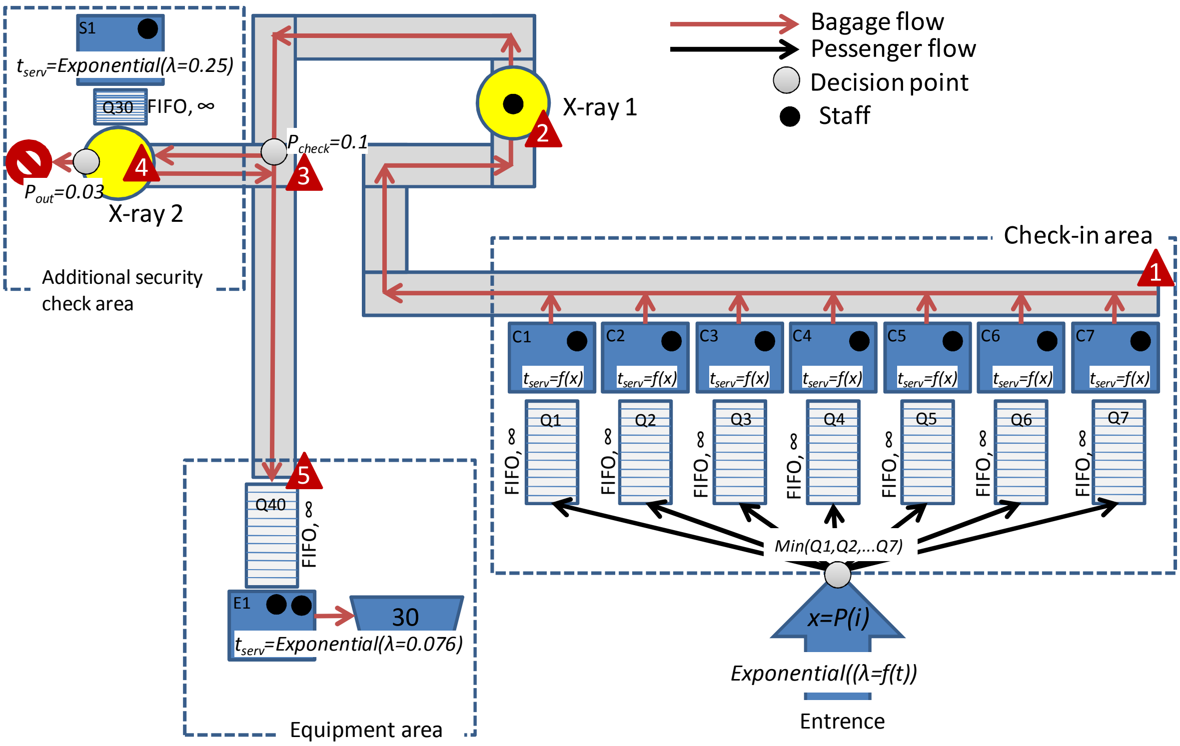
That is why it is necessary to estimate the effect of passengers' number growth on BHS. For this purpose a simulation approach was chosen. According to (Savrasovs 2008) we can simulate systems on 3 levels: microscopic, mesoscopic and macroscopic.



Figures 1: Scheme of BHS in Riga Airport

The check-in and equipment areas can be called the main problem zones in airport. On the screen of the passengers' number growth these places could become a bottleneck of the whole system.

For this work there was used the discrete-event approach which belongs to the microscopic simulation.



Figures 2: Conceptual Model of the System

The reasons of using the exactly discrete-event approach could be described as follows:

- graphical representation of model must be presented for validation and visualization;
- static and dynamic output must be acquired from the model;
- event-based characteristics of real system

CONCEPTUAL MODEL DESCRIPTION

Before creating the model, the conceptual model should be implemented to ease of understanding of the simulation object. Because the simulations object is very complex some simplifications were done. These simplifications could be easily explained using the conceptual model described in figure 2.

As could be seen in the figure, only 7 check-ins will be modelled. Such decision is connected with the other decision to model only the peak-hours in the airport. For Riga airport those hours are from 17:00 until 20:00.

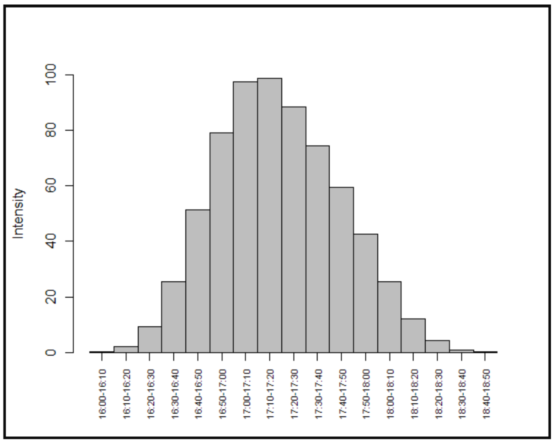
Mostly these hours are used by the AirBaltic company. That is why only check-ins, which serve the AirBaltic flights are taken into account in the model. The luggage service process was left as described above. The key point of this process could be described in details.

In general the arrival process of entities (passengers) is presented as the poison flow with one parameter – intensity. The problem is to determine this parameter, because there were no surveys done in the airport estimating process of passengers entering. But the intensity could be estimated doing the documentation survey. The flights between 17:00-20:00 are mainly the same every day. And the numbers of flights are 14 in this time period. The mean number of passengers for each flight was calculated using the airport documentation. The start of registration is at 120 minutes before the airplane departure. The registration for flight is limited to 100 minutes. So we have got the interval of time of 100 minutes and we have got number of passengers, who came during this time to the registration. Using experts it was determined that the peak of passengers goes between 40-60 minutes before the end of registration. To share the number of passengers at this time period we have used the binomial distribution and Bernoulli formula. The interval of 100 minutes was divided into 10 subintervals and for each interval the probability of passengers appearance was calculated.

$$p_k = C_n^k \times p^k \times q^{n-k}$$

, where n=9, *k= {0..n}, p=0.5, q=1-p*

Such procedure was done for each flight. The probabilities were calculated and multiplied by the number of passengers for one concrete flight.



Figures 3: Intensity of Passengers' Arrival Dynamics

The procedure was done for each flight. Data were aggregated for the whole modelling time and the intensity for each subinterval was calculated as could be seen in figure 3

Passengers choose the check-in based on the minimal queue length rule. During the process of registration the passengers must leave their luggage. To define the number of the baggage per person, empirical data were used. The maximal number of luggage per person is 5 items, the minimal is 0. The probabilities are presented in table 1.

Table 1: Probability of Luggage Count

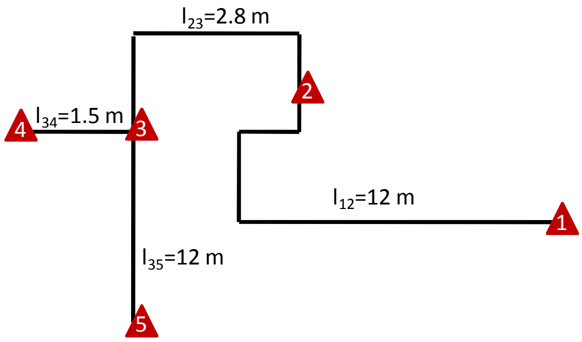
Items count	0	1	2	3	4	5
P_i	0,15	0,65	0,15	0,03	0,01	0,01

The process of registration in general, has fixed the time and depends only on amount of luggage and could be calculated using function below.

$$f(x) = \begin{cases} 30 + x \bullet 15, x \le 5 \\ 105, x > 5 \end{cases}$$

where *x* is the amount of baggage items.

So to calculate the time which check-in staff will use to serve the client we are using the constant 30 seconds to register person plus 15 seconds for each luggage item. This time was estimated directly from the check-in staff work observation.
After registering the luggage is put to the conveyer and it starts moving with the constant speed of 0.2 meters per second. The length of the conveyer parts is shown in figure 4.



Figures 4: Conveyer Length

Also here should be mentioned that the probability of the positive decision (needs additional checking of luggage on x-ray point 2) on x-ray point 1 is 0.1. The time of the additional check is distributed by the exponential law with the mean 4. The probability that baggage will be restricted for delivery to the airplane is 0.03. There are two persons in the equipment area who serve luggage sequentially, wasting on each luggage item the time distributed by the exponential law with the mean=13 seconds. Then a luggage car is filled with 30 items of luggage it is send to airplane.

MODEL DEVELOPMENT

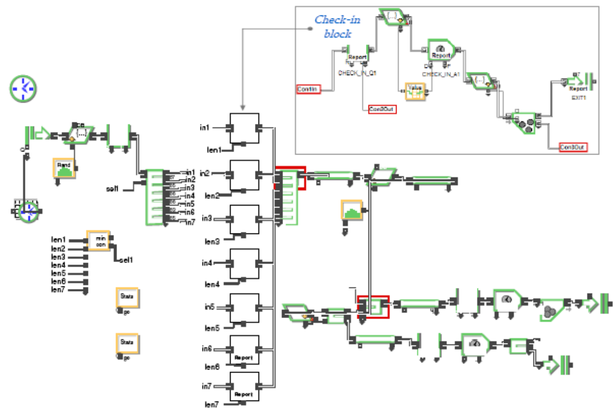
As the tool of the model constructing there was used the simulation software ExtendSim from ImagineThat Inc. The reasons of selecting exactly this software can be enumerated:

- Modern simulation system, which has the discrete-event simulation module
- Opportunity of creating 2D and 3D graphical representation of the developed model
- Embedded programming language, which gives more flexibility in logics
- Number of blocks in the discrete-event library which could be used directly
- No limitations on the number of objects used during model development
- Wide number of different random number generators, which can generate the uncorrelated random sequences
- Manager of runs, which does simplification of data collection during runs

Also there could be mentioned that the ExtendSim is widely used in the simulation community for research and analysis. This could be seen from the analysis of the publication at the Winter Simulation conference. The examples of using the ExtendSim for simulation in different application areas could be found in (Damiron and Nastasi 2008; Kopytov et al. 2008; Weiss 2008). In general, the model was developed using the following ExtendSim libraries: discrete-event, item, utilities, value and animation 2D-3D. The item, utilities, value and animation libraries were used as helping libraries for the data collection random numbers generation and visualization. Using discrete-event library objects such as generator, queue, activity, conveyer, combine base model was created according to the conceptual model. The numerical characteristics of the developed model could be mentioned:

- 117 ExtendSim blocks
- 300 connectors
- 2 submodels
- 20 labels
- 29 additional blocks for 3D animation implementation
- 7 blocks for statistics collection

The developed model is presented in figure 5. The presented figure shows that for implementing check-in there was used the sub-model, organized as hierarchical-block. Such approach simplifies the process of using similar parts of model. Also on the base of the implemented model the 3D animation was developed for the visualization and validation purpose. It was done by means of the animation 2D-3D library of the ExtendSim. The base model was completed with special objects.



Figures 5: Model Developed with the ExtendSim

The 3D representation of the model could be seen in figure 6. Using developed 3D animation the base model was validated by means of the experts' approach. Having used animation, the experts concluded that the developed model is valid. The further animation demonstrated different scenarios during the experimental part of work.

EXPERIMENTS PLANNING AND REALISATION

The developed base model was further used for the experiments. There were developed 3 possible scenarios which were played on the model. The description of scenarios could be found in table 2.

Figures 6: 3D animation of the Developed Model

During the experiments the realisation of the structural changes was done in the model. 50 runs per experiments were executed using ExtendSim runs manager. For data collection there were used the blocks from the library value and blocks statistics. During experiments the following characteristics were estimated:

- Utilization of staff in check-in, additional security check and equipment area
- Passengers' queue characteristics (average, maximal)
- Baggage queue characteristics (average, maximal) for the additional security check and equipment area

Table 2: Scenarios Description

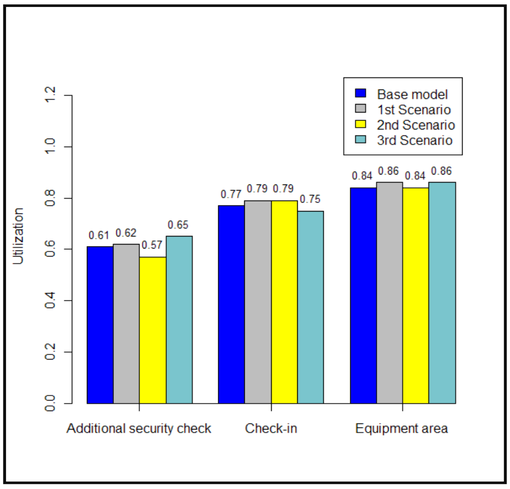
Nr.	Description
1	• Passengers' flow increased by 15% (forecast until 2010) • Number of check-ins is 7
2	• Passengers' flow for 2010 (15% growth) • 10 check-ins • New staff on 6 check-ins (passengers' registration – 50 seconds, 19 seconds per luggage item)
3	• Passengers' flow for 2010 (15% growth) • 10 check-ins • Passengers' and luggage registration time the same as in the base model

The data processing demonstrates that there were some outliered runs in each experiment so these runs were removed as not valid. For the first experiment the number of not valid runs was 3, for the second - 5 and for the third - 6.

RESULTS ANALYSIS

The collected data were analyzed using statistical software (Venables and Smith 2005). The main results could be presented in details visually.

Utilization



Figures 7: Utilization Level on Different BHS Areas

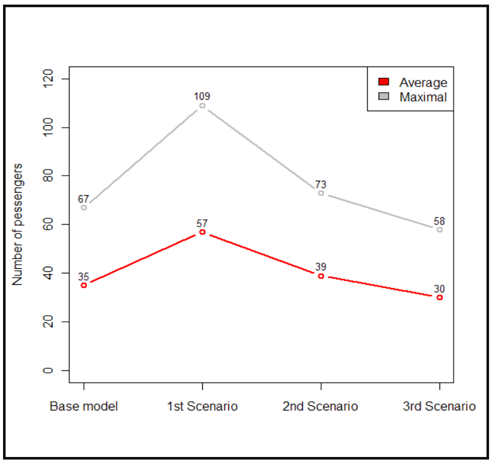
The utilization is used as one of the most important characteristics for determining staff loading level. The figure 7 shows utilization level for 3 different areas of the BHS through 4 earlier described scenarios. The base model is the model, which represents the current situation of BHS. The first cluster of bars deals with the area called "Additional security check", second "Check-In" and the last one "Equipment area". Current mean utilization throw all check-ins is 0.77. This value is relatively in comparison to the normal staff loading level from 0.65 to 0.7. The planned increasing of the number of check-ins in the second scenario does not change the situation, the value of the utilization level becomes worse by 0.79. This points out that the number of check-in plays a big role, but also staff qualification is important and the heads of airport should pay attention to this factor. The last experiment proves that by increasing the number of check-ins we could decrease the utilization, but still decreasing is too low.

All 4 values of utilization for equipment area are high and do not correspond to the implemented normal level of staff loading. Also there should be noted that the variation of utilization level is very low. It means that the passenger flow growing almost does not have influence on the equipment area staff loading. But the reasons of this should be explained.

Also the small variation could be observed in the bars for the additional security check. The values lie in normal range.

Passenger's queue length

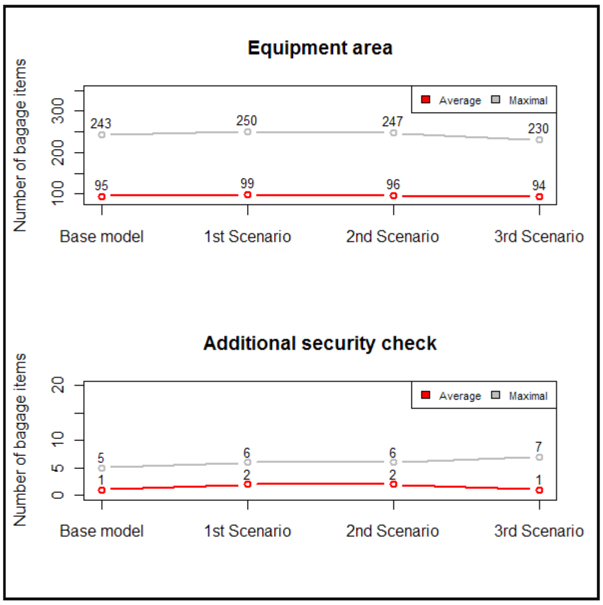
This characteristic is used only for check-in, because only check-ins deal with the passengers, all the other work with the luggage. In figure 8 we can see average and maximal characteristics of queue length. The values are calculated through all check-ins.



Figures 8: Average and Maximal Passengers' Queue Length on Check-in

As could be seen the current average passengers' queue length is 35 people and the maximal value is 67. In the first scenario the dramatical changes could be observed. The average length is growing to the value of 57 passengers, but the most important that there is the maximal queue length reached level of 109 passengers. This one is important because the place in the airport near check-ins is limited and as a result the area overloading can happen, which will influence the customers' service level. In the 2nd and 3rd scenarios the value is decreasing and reaches 30 passengers, in average, in the 3rd scenario. Also the maximal value is acceptable.

Baggage queue length



Figures 9: Average and Maximal Baggage Length

The luggage queue can appear in two areas. They are equipment area and additional security check. The figure 9 shows the average and maximal number of items for each zone. Using this result we could conclude that passengers flow growth does not influence match on the presented characteristics. In average there no difference between base model and the 3rd scenario for both areas. But it should be mentioned, that the queue length in the equipment area is very high - 94 items, in average. At the same time the high utilization level for this area (see figure 5) points out that the staff is overloaded. Because of that, this area could be treated as the bottleneck for the system.

CONCLUSIONS

- The model of Riga's BHS was constructed using simulation on the microscopic level, applying the discrete-event simulation approach. As a tool of the model development there was used ExtendSim simulation package. The animation was created for the visualization and validation purposes.
- The input parameters for the model were estimated during document surveys and natural observations of BHS work. Passengers' flow intensity estimation was the main problem during model parameterization. It was successfully solved using binomial distribution and Bernoulli formula.
- 3 different scenarios were implemented for HBS analysis. All of them are based on the hypothesis that during passengers' flow growing, the bottleneck of the system will be in the areas where the manual baggage processing happens.
- Different characteristics were calculated during experimentation. The most important one is the utilizations coefficient for different areas of BHS. The staff loading in the check-ins and equipment area is high and does not fit to the normal defined range. The variation of utilization level is very low. It means that the passengers' flow growing almost does not have influence on equipment area staff loading. This could be explained by the reason that the bottleneck appears between the check-ins and equipment area. Because of the utilization in the check-in is lower than in the equipment area and there is no manual baggage processing between these two areas, we can conclude that the hypothesis that only the staff factor will be the bottleneck in future, could be rejected. The automatic processing should be also taken into account. Speed and conveyers capacity must be increased. At the same time according to the data, the equipment area could be treated as the bottleneck of the system, because of high queue length and high utilization. The additional personnel are required in this area or the baggage sorting must be done automatically.
- The baggage registration procedure must be simplified and self-service possibility should be implemented, because the number of passengers waiting for registration could grow dramatically. Also the increasing number of check-ins could

solve this problem, but staff should have a very good qualification.

- The research must continue to estimate the other scenarios connected with implementing the new conveyers and integrating automatic systems.

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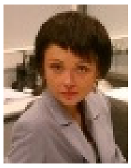
AUTHORS BIOGRAPHIES

MIHAILS SAVRASOVS was born in Daugavpils, Latvia and entered the Transport and Telecommunication Institute where he studied computer science and obtained the Master's degree of Natural Sciences in Computer Science in 2006. He is a student of TTI Doctoral degree programme "Telematics and Logistics". Current position: Head of the Laboratory of Applied Software Systems in the Transport and Telecommunication Institute, lecturer of Mathematical methods and modelling chair. Fields of research: applied statistical analysis, modelling and simulation. Publications: 7 scientific papers.

E-mail: mms@tsi.lv

ALEXANDER MEDVEDEV was born in Alma-Ata, Kazahstan. He entered the Riga Civil Aviation Engineering Institute, where he studied mechanical science and obtained his Engineer's diploma in 1985. Dr.sc.ing. (1995), Riga Aviation University. Present position: Professor; Head of the Transport Chair; Programes: "TRANSPORT MANAGEMENT" and "COMMERCIAL OPERATION OF TRANSPORT". Member of the TTI Research Committee, Member of the Latvian Operation Research Society, Member of Latvian the Higher School Professors' Association, Lecturer of Learning Training Transport and Logistic Consultative Centre and the Training Centre "Latvijas Auto". Fields of research: transport and logistics. Publications: 3 inventions and 70 scientific papers and teaching books.

E-mail: man@tsi.lv



JELENA SINVOCA was born in Riga, Latvia and entered the Transport and Telecommunication Institute where she studied according to the transport and business logistics programme and obtained the professional diploma in 2007.

E-mail: jelena_sincova@mail.ru