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Passenger Terminal Safety: Simulation Modelling as Decision Support Tool

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Abstract

The paper demonstrates the possibility of using simulation modelling for improving the processes of managing the development of the terminal at a strategic level, taking into account, first of all, security and safety aspects of quality of services. The described in the paper developed simulation model based on the AnyLogic software could be treated as decision support tool for management of the passenger terminal. The background of the problem is related with the started reconstruction process of the terminal with no ability to close it for reconstruction period. The decision to temporary close different parts of the platforms and make step-by-step reconstruction was done by management. But this decision causes a number of question regarding safety aspects of the passengers. The developed simulation model is directed on estimation of the passengers' density in terminal. The higher density directly influences the safety issues. The primary task of the developed decision support tool is to support management of the terminal with quantitative values of passenger density for different scenarios of reconstruction.

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Keywords: passenger terminal; analysis; safety, security; simulation; discrete-event; agent simulation.

1. Introduction

EC "A sustainable future for transport: towards an integrated, technology-led and user friendly system" (Communication EC… 2009) states that the overall quality of transport including personal security, reduction in accidents and health hazards must remain a high priority in transport policy. The Transport White Paper sets out the

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EU transport research, innovation and deployment strategy, which should support development and deployment of technologies and solutions for better and effective use of transport networks, and safer and more secure operations through information and communications systems (White Paper 2011). These solutions should be (SecureStation… 2015):

- innovative;
- to improve the security level – quantifiable, to improve risk assessment or management capability, to improve the security level in any aspects;
- to be reusable which refers to the adaptability of the capacity to different environments than that for which it was designed with slight or no modification: facility to use new technologies in different situations, common language for all the stakeholders involved, modularity, interoperability, standardization;
- applicable to real environment, which included minimum cost, scalability, reliability, availability, maintainability, safety.

By definition a coach terminal is a linear construction consisting of specific buildings, platforms and a territory for the rendering of services to passengers and coaches during the routes (Rodrigue et al. 2013). To ensure an effective operation of such a linear construction, to be able to render high quality services both to passengers and to haulers in conformity with their needs, the functions and operational activities of a coach terminal have to be evaluated at a larger scale (Gromule, Yatskiv 2007). In context of accessibility, users require that passenger terminal to be accessible as possible and could include all necessary in context of space and equipment for free and safety movement. On the stage of space planning usually define the size, type, number, and functional relationship of facilities needed for passenger terminals and include their security requirements. Because of the concentration of vehicles and passengers' accumulation, the problem of increasing the level of safety and security becomes more significant. Passenger terminals may appear congested at certain pick-hours, but the flows of people can be managed successfully with good design of platforms, access points, and with appropriate scheduling of arrivals and departures. As a result that the amount of time passengers spend in such terminals tends to be brief, terminals tend to be made up of simple components, from ticket offices and waiting areas to limited amounts of retailing (Rodrigue et al. 2013).

The article is focused on the problem of accessibility and safety analysis in terminal and presents a conception of decision support tool for recognition of the critical situations with these aspects on the transport terminal on the simulation modelling of Riga International Coach Terminal (RICT). RICT is a leader in the area of bus transportation services in Latvia and security and safety in passenger terminal is core condition for the customer satisfaction towards a service. The RICT management is considering encouraging use of the terminal capacity in order to improve the returns on its investments (A/S „Rīgas Starptautiskā… 2013).

According to David (David 1999) a bus terminal is an area away from the general flow of road vehicles, which enables buses and coaches, to drop and pick up passengers in comfort and safety. Moreover, as mentioned in (Faulks 1977) the most important determinant of user satisfaction with a transit station is reliable service in an environment of personal security, and only indirectly the physical characteristics of station. Meyer (Meyer2008) notes that appropriate spatial arrangement and zoning of the various segments of a bus and coach terminal is of uttermost importance as the bring about free flowing traffic within the terminal. There are studies presenting evidence for using in decision-making process special analytical tools including simulation modelling. This is shown, for instance, in (Hanisch et al. 2005) where the use of online simulation of pedestrian flow in public buildings give the possibility to improve the aspects of safety and short-term planning in the phase of organizing and operating large public buildings. These might be places such as a train station, an airport, bus and coach terminal etc. Moreover, public engagement can be considered as the process of achieving a transparent decision-making process with greater input from stakeholders and their support of the decisions that are taken (Cascetta, Pagliara 2013). And for this, some of the analytical and visualisation tools can be used for the various levels of decision making. The authors describe the role of these tools in planning and designing transportation systems, describing its interactions with other more formal phases of decision-making with the example of the Regional Metro System project of Campania region in Italy.

The RICT management has the strategic project for significant improvement of service quality in RICT. This project takes into consideration the existing design of passenger terminal and the "temporary" designs for the period of its reconstruction. The main essence of “temporary” design in process of reconstruction is to provide a terminal, which would ensure the safety and comfort of passengers before and after journeys. The vehicles and passengers movement simulation have been applied and used to suggest modifications to RICT in process its reconstruction. The objective of this research is to highlight the role of simulation modelling at the stage of passenger terminal reconstruction and show it on a particular terminal which is located in the centre of the Latvian capital and is the essence node of Riga transport network.

Although a number of various professional simulation solutions, specializing in passenger flow simulations in rail, metro and bus stations, exist. For instance, SimWalk Transport (http://www.simwalk.com/simwalk_transport/index.html) allows modelling realistically passenger flows, boarding and alighting, different rolling stock, varying time schedules, train switching and much more. Unfortunately, all of them are very expensive and many private companies can’t use them for decision making process. From the viewpoint of practical applications, flexibility, ability to combine the different approaches of simulation the AnyLogic 6.9 software (Anylogic.com 2015) was selected as the model development tool.

The paper will present the methodology of the problem decision based on simulation modelling. In order to solve the weakness of the existing projects of terminal “temporary” designs simulation used ‘discrete-event’ and ‘agent simulation’ paradigms will be presented and tested on the base of empirical data of RICT. It will be shown that this approach has potential to serve as a suitable instrument for managing the development of the terminal at a strategic level, taking into account, first, security and safety aspects of the quality of services.

2. Methodology

Solving the tasks of management in complex systems today lies in the sphere of designing of decision support system (DSS) and the main decision is paid to the process, not to the result of the decision or the essence of the problem. Decision-making is a conscious choice between the existing variants or alternatives of the direction of actions, which reduce the break between the present and the future desired state of the object of management. Thus, the given process includes a great number of different elements but it always has such elements as; problem, goals, alternatives and decisions – the choice of an alternative. Figure 1 presents the stages of the process of the decision making support the task of monitoring of the quality of the terminal services, which aim is improving the manageability of the passenger terminal.

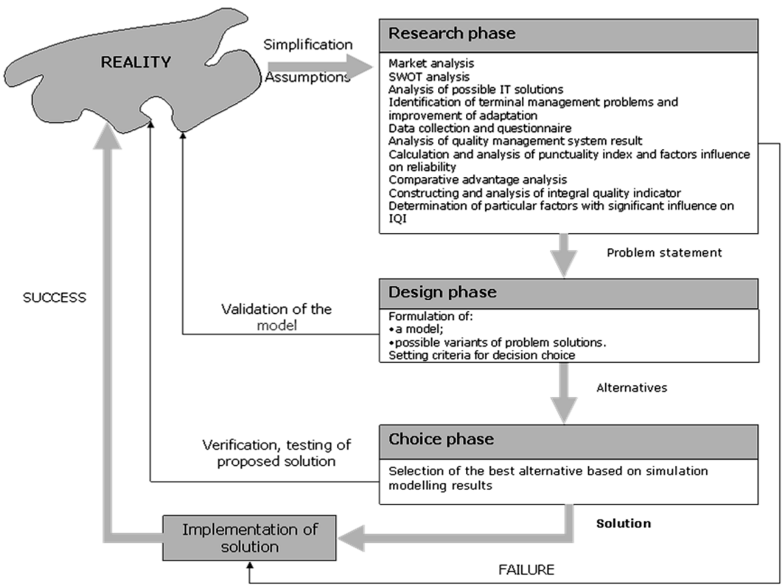

Fig. 1. Stages of decision-making process (Vaira Gromule’s 2010).

At the research phase there was made the SWOT analysis of the existing terminal functioning. There have been determined the significant factors for the development of a terminal. There have been considered the possibility of the additional instruments for realizing a new systematic approach to monitoring of the service quality. The offered instruments allow due identification of a problem in the manageability of an coach terminal and setting a task for making decisions on the adaptation of the terminal to the changing conditions.

The decision of the reconstruction (planning) of the transport infrastructure is one of the most important decisions, which need thorough prior consideration. Often, in making project decisions there is lack of sufficiency and clearance of the technical-economic information. Therefore, the decision maker will have to deal with uncertainty and risk. In this connection, the problem of the decision making support in choosing a project decision on building new and reconstructing the existing transport infrastructure objects acquires special actuality and requires improvement of the methodology of its decision. With the application of the analytical instruments developed to the Riga International Coach Terminal data, there have been revealed the crucial factors from the point of view of the provided service quality (especially safety and security).

In designing and reconstructing a Coach Terminal, it is important to take into account the space of the terminal from the point of view of the number of the trips under service and the passenger turnover, general and market segmented – international, inter-city and regional trips. Provision of the possibility of the passengers' transfer in a multimodal system of passenger transportations is also important. Therefore, the criterion of choosing a particular decision on a "temporary" terminal design is the complete meeting of transportation demands in peak hours.

For building, the model there have been used the data of the RICT (from Information System "Baltic Lines"):

- buses' timetable during the day;
- characteristics of employed buses;
- statistics of the buses' congestion, etc.;

and the data which present one of the alternatives of solving the problem – the design of a new terminal with platforms, schemes of buses' entrance and departure from/to the territory.

The model is built based on the simulation software AnyLogic and allows modelling transport and passenger flows at the micro level. Figure 2 shows the detailed stages of model development for coach terminal.

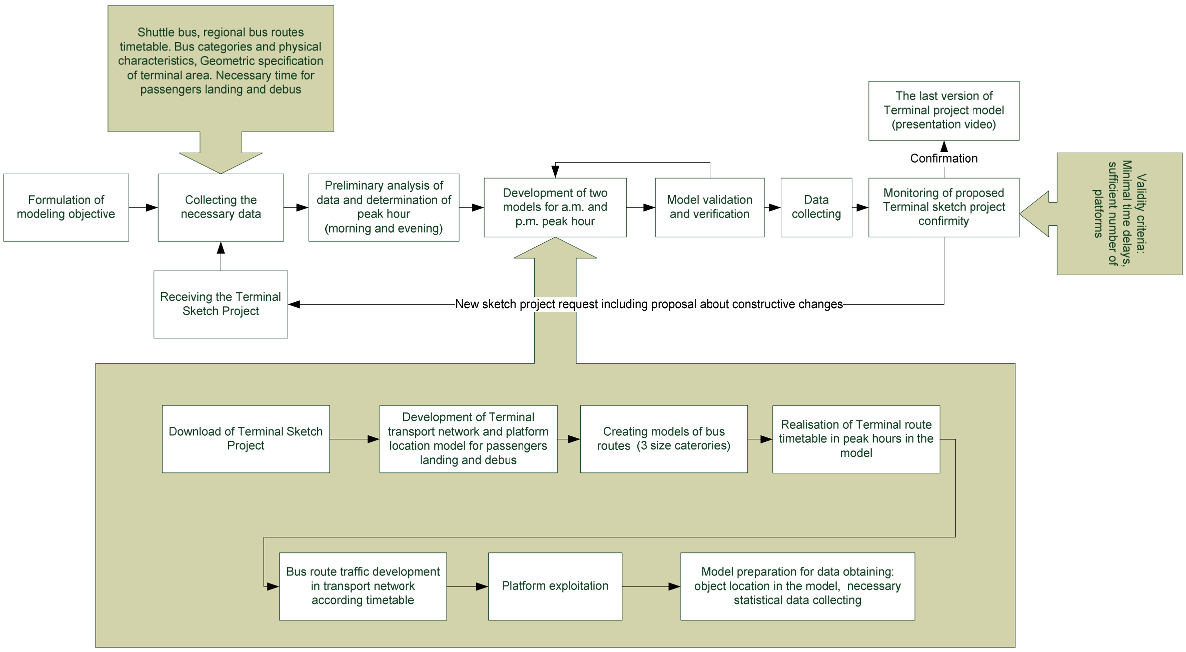

Fig. 2. The detailed stages of model development for coach terminal (Vaira Gromule's 2010).

In the process of modelling there have been revealed “the narrow places” of the supposed ‘temporary‘ design; their analysis and elimination were performed at the stage of designing and preparing of the final decision on the design of the terminal in process of reconstruction.

3. Model development

Taking into account the requirements set by customer, the AnyLogic 6.9 software was selected as the model development tool. The main advantages of the selected software are the following: flexibility, ability to generate JAVA applets and standalone applications, ability to develop of hybrid models as well. The number of publications could be listed here as a good example of AnyLogic application for transport hubs simulation from the point of view of passenger’s flows. For instance, in (Li et al. 2014) the example of AnyLogic use for passenger flow simulation on urban subway station was provided, in (Zhang, Yi 2013) mentioned use of Agent Based approach for simulation passengers flows in urban railway network, the business case of application of AnyLogic for simulation passengers flows in railway station is described in (Anylogic.com. Passenger Flow Simulation for… 2015), business case of passenger flow simulation in airport building with use of AnyLogic software is presented in (Anylogic.com. Passenger Flow Simulation at… 2015).

The popularity of this tool is closely linked with the ability to create the so-called hybrid models or mixed models (Borshchev 2013). Here under hybrid models is understood the ability to combine different simulation approaches in one model. This feature allows to speed-up development process and increase validity of the model by using more appropriate simulation approach for different parts of the model. In this case, two approaches were mixed together: Agent Based simulation and Discrete-event simulation. Agent-based simulation was used in form of Pedestrian library to simulate passenger’s flows in bus terminal. At the same time, Discrete-event simulation was applied to simulate buses arrival process to the terminal, movement in territory of terminal etc. It must be noted that, despite the fact that AnyLogic has Road Traffic library, which is also based on Agent based approach, after testing the library, the decision to use Discrete Event simulation was taken, as existing version 6.9 of Road Traffic library has a number of disadvantages and limitations, which makes hard to apply it for such types of tasks raised in the frame of the work. These disadvantages must be taken into account during development transport models in AnyLogic: no special tools to simulate traffic light, no collisions detection and avoiding on crossroads, no special tools to define vehicle complex behaviour (at example choosing less busy line), and reverse moving of the vehicles (Anylogic.com. Online… 2015). At the same time AnyLogic provides flexible environment with programming capabilities, which allows defining a very complex behaviour of dynamic object inside the system.

The following data (see Table 1) were used as the input parameters for the simulation mode and were provided by the customer.

Table 1. Input data for simulation model.

Type of data	Description
Bus terminal and platform drawing in DWG format.	The data used as background in simulation model in order to describe simulated environment. Based on data walls and restricted areas in terminal were defined using standard AnyLogic tools
Schedule of incoming and outgoing busses with linkage to the platform	Data were used to define incoming and outgoing transport flow in terminal. Each arrival and outgoing bus was assigned to specific platform
Schedule of ticket office operation and service time	The data defines number of operating ticket offices, taking into account schedule and average service time of the passengers
Probability of having travel ticket (bought throw internet)	The data were provided in tabular form, showing number of sold tickets and number of sold tickets throw internet. Based on data a probability of having ticket were calculated
Number of sitting places in waiting hall of the terminal	As terminal has waiting places, which are used by passengers, this issue was included into the model.
Empirical data about arrival process of the passengers for the busses (see Figure 3).	Using provided (in form of tables and in from of video files from security cameras) data it was possible to estimate the arrival process of passengers to the terminal

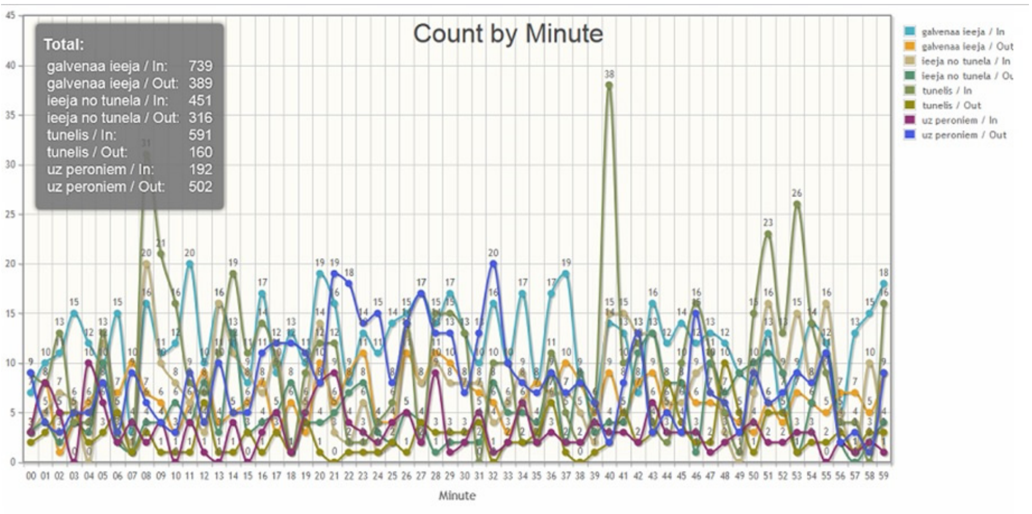

Fig. 3. Passenger count data by minute.

The data mentioned in Table 1 were processed and transformed to the suitable format for AnyLogic software. The model by itself could be split in three logical parts:

- Passenger flow simulation model – the model describes the behaviour of the passengers (arrival, waiting places, moving between different zones of terminal, platform allocation);
- Ticket desk simulation model – the model defines operation of the ticket desk based on the schedule and data about service time;
- Transport flow (buses) simulation model – the model represents the arrival, moving, platform allocation, and debarkation process of the buses.

The passengers flow simulation model is simulated by means of standard blocks of the Pedestrian library of AnyLogic software. The example of the part of the model is presented on Figure 4.

Here must be mentioned, that passenger behaviour processed is described using standard blocks, but with some particularities: arrival process of the passengers is controlled manually (programmatically). It is needed to link the arrival process of passenger with a concrete trip. Based on empirical data it was estimated the percentage of passengers coming 60–50 minutes before departure, 50–40 before, 40–30 before, 30–20 before, 20–10 before and finally 10–0 minutes before departure. Based on time until departure the following behaviour is assigned to the passengers:

- if time till departure is >40 minutes the passengers are assigned to the waiting hall with waiting time up to 15 minutes, after the stochastic movement on the territory of bus station building is assigned in average 10 minutes. At 10 minutes before the departure the passengers are assigned to follow to the departure platform;
- if time till departure is <40 minutes the stochastic walk around is applied, and as in previous condition 10 minutes before departure the passengers are assigned to follow to the departure platform.

Ticket desk simulation model is based on standard blocks of the AnyLogic with active use of schedule objects. Based on real data the schedule defines opening and closing hours for each ticket desk. The ticket desks continue to serve passengers even if they are already out of service until the queue for this ticket desk will become empty. Based on data from video the queue growing directions (and the form) was defined for each ticket desk using standard tools of the AnyLogic.

Transport flow (busses) simulation model – the model represents the arrival, moving, platform allocation, and departure process of the busses. The simulation was done based on Discrete Event simulation, because of the earlier mentioned Road Traffic Library limitations. The standard blocks of the AnyLogic were used to simulate the whole process.

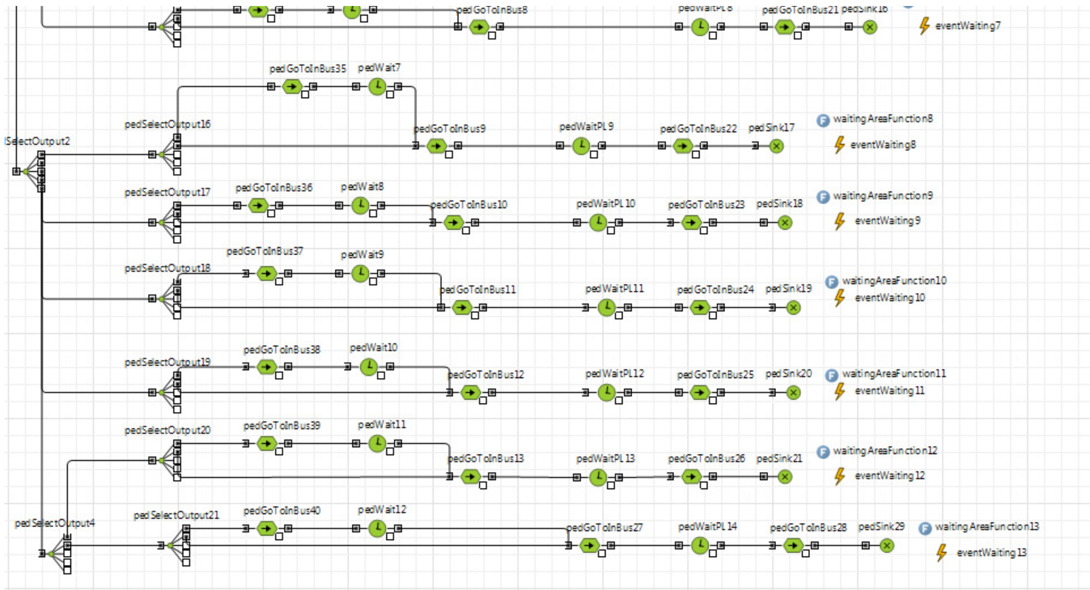

Fig. 4. Part of the passenger arrival and waiting process simulation.

Figure 5 represents part of busses arrival process (represented for each arrival and departure platform) and the part of the model, which represents the allocation of the platform process. It is assumed that busses arrive at the terminal without delay, but because of the intensive traffic in the terminal territory, it could arrive to the platform with the delay. In this case, as soon as all passengers located in the platform will be loaded to the vehicle, the departure happens promptly.

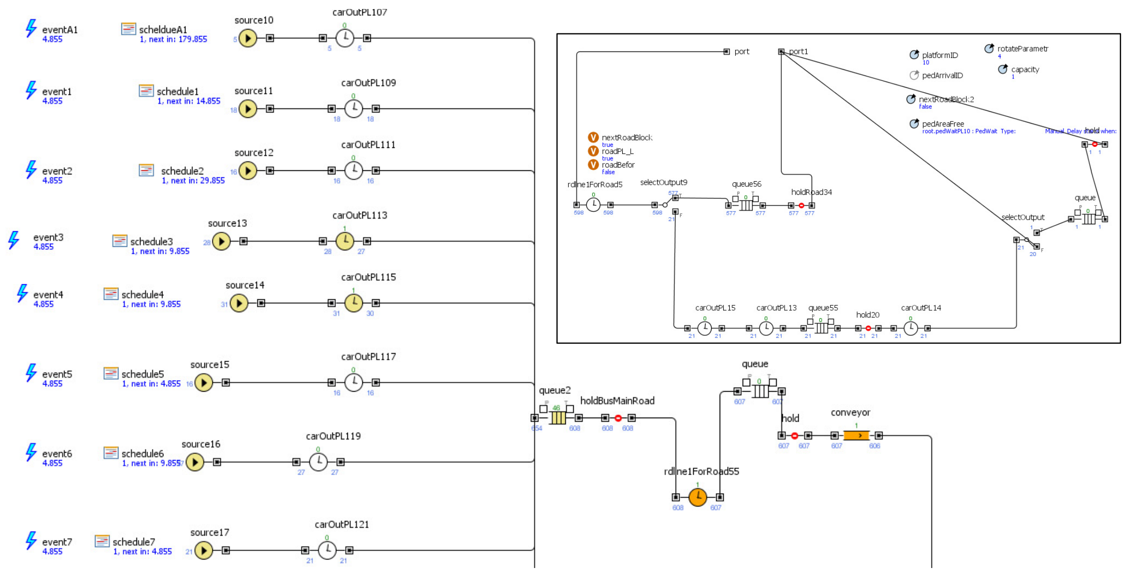

Fig. 5. Part of the arrival and platform allocation process.

According to the requirements, the models consist of four screens (starting screen, model 2D visualisation screen, model 3D visualisation screen and screen which represents statistics). The movement between screens is controlled by the user during simulation. The user has build-in possibility to control model execution speed and quality of the graphical representation.

2D model provides an animation of the simulated processes and at the same time generates the image with pedestrian density. 3D model of the processes could be used as representation materials and finally statistics tab provides data about dynamics of the density, minimum, maximum and average density for each platform, waiting hall and main hall in the territory of terminal.

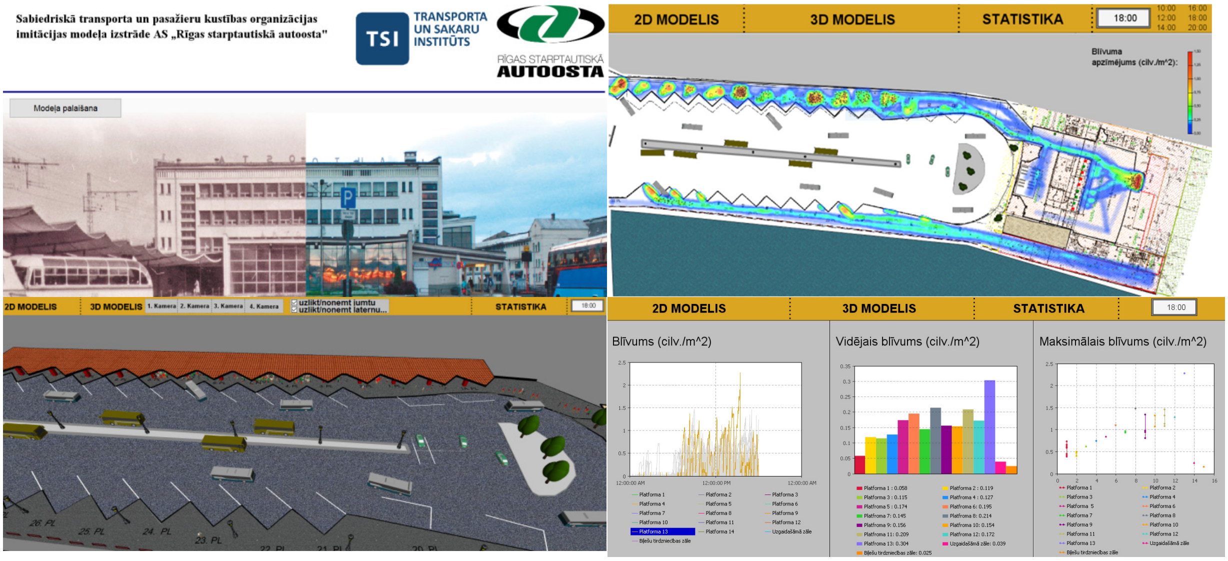

Fig. 6. User environment of the model (in Latvian).

4. Experiment planning, results and discussion

The developed model was used to check possibility to temporary close some of the platforms, because of the reconstruction in terminal. The bus routes assigned to temporary closed platform are assigned to other platforms. The Figure 7 demonstrates conditions for 2 planned experiments.

Following experiments were planned:

1. Temporary close platform with numbers from 8 to 13 (platforms are represented on Figure 7 and are marked by green circle).
2. Temporary close platform with numbers from 1 to 7 (platforms are represented on Figure 7 and are marked by green circle).

The experiment, which represents current state (before reconstruction) will be called a base experiment. The experiments will be done with following conditions: a) the peak hours are simulated (8:00–10:00); b) number of runs for each experiment – 10 runs. The main characteristic, which will be observed during experiment, is a density of passengers on platforms as this directly influence to the safety of terminal. The results, which obtained based on completed experiments with model era presented in Table 2. As we see from the Table, there are some visible changes in density (highlight by grey). However, in order to test significance of the difference the t test was applied to check homogeneity between base experiments data and data obtained during the other experiments. The difference between density for 1 Platform (base vs first experiment) is significant with $t = -9.019$ (p-value<0.01). The other results were obtained and are presented in Table 3.

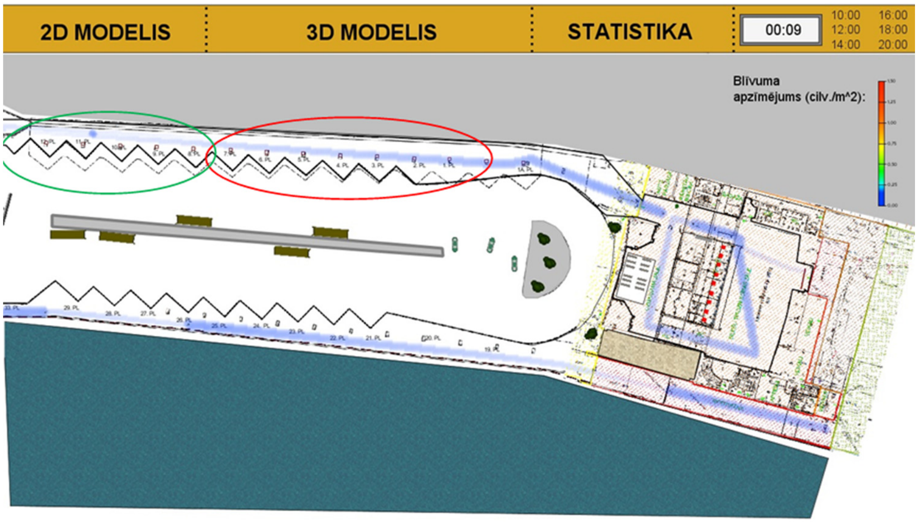

Fig. 7. Temporary closed platforms for 1st and 2nd experiment (in Latvian).

Table 2. Passenger density (pass/m^2).

Platform Nr.	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
Base	0.021	0.149	0.249	0.13	0.272	0.289	0.197	0.335	0.1	0.18	0.411	0.298	0.585
1	**0.155**	0.165	0.165	0.232	0.218	0.222	0.159	**Platforms are closed**					
2	**Platforms are closed**							0.324	**0.302**	0.183	0.464	0.25	0.31

Table 3. t-test results.

Platform Nr.	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
T test	–9.019	–1.187	3.980	–5.805	3.392	2.178	2.785	.889	–9.604	–.205	–3.54	1.393	9.501
p-value	<0.01	.238	<0.01	<0.01	<0.01	.031	.006	.376	<0.01	.838	.001	.166	<0.01

The following conclusions could be done based on the obtained data: no significant differences between base experiment in case of platforms: 2, 8, 10, 12. In case of platform 1, 3, 4, 5, 6, 7, 9, 11, 13 the difference is significant.

Management of the terminal, taking in to account critical limits of the density, is able to make a decision about possibility of this solution. In case of high density on platform the decision about moving bus arrival/departure platform will be changed or even provided changes in timetable in order to avoid not safety conditions on terminal.

5. Conclusions

The article gives an example of applying simulation modelling as an analytical means of the DSS at the stage of planning of reconstruction of passenger terminal. In order to solve the strategic weakness of the offered 'temporary' decision of reconstruction it is need to ensure effective spatial arrangement through activities' zoning. Consideration of the current and projected passenger counts, current and planned layouts for identifying where the offered design for station reconstruction allowed safe aggress in capacity.

The research has demonstrated how the simulation model at the stage of processing the alternative for the planned decision allows:

- revealing advantages and disadvantages of the planned decision;
- analysing the suggested variants of the buses' traffic and of the passengers' flow in the terminal;

- analysing the sufficiency of resources (platforms, for example) for performing the timetable of the bus traffic and the convenience of their allocation, etc.

The detailed description of the constituents of this process and demonstrates the realisation of the process of the decision making support for passenger terminal with the data of a real terminal are presented in the article. The research shows the possibility of better identification, with the help of the developed analytical instrument possible alternatives and of making decisions for providing functioning and development of the terminal in the period of its reconstruction operatively reacting to the necessary changes. This approach has potential to serve as a suitable instrument for managing an effective and efficient safety and security concepts development in Riga Bus and Coach Terminal.

Acknowledgements

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