

Simulation modeling of infrastructure objects as a management tool of intelligent transport system

E. Volkova^{1*} and A. Romanov¹

¹Emperor Alexander I St. Petersburg State Transport University, 190031, Moskovsky pr., Saint Petersburg, Russia

Abstract. Nowadays, the formation of intelligent transportation systems is taking place, allowing to increase the efficiency of transportation through the use of innovative technologies. Methods and means of simulation modeling have gained considerable popularity among them, allowing to increase the accuracy of forecasting and efficiency of management decision-making. The purpose of this article is to develop the directions of application of simulation modeling in the field of passenger transport infrastructure management. The article presents the results of applied research using simulation modeling tools of passenger transport infrastructure objects. Based on these results, the effects of using simulation modeling methods in the management of passenger transport system are systematized. In order to achieve the research goal, a review of scientific works was conducted, the areas of application of simulation modeling in the management of passenger transport infrastructure were specified, the effects of using simulation modeling methods and tools were analyzed and generalized. The results of the research can be useful to transport organizations, state regulation bodies on transport and organizers of transportation. They can be used in the construction of scenarios for the development of transport infrastructure objects to improve the quality of service to the population and to ensure the effectiveness of management decisions on transport. Keywords: Passenger Transportation, Intelligent Transport System, Digitalization, Intelligent Transport System, Simulation Modeling, Transport Infrastructure.

1 Introduction

At present, transport systems, including passenger transport systems, are undergoing a transformation in both technical and organizational and management aspects. Due to the development of digital technologies, new ways of providing transportation services, business models, planning and management technologies are emerging. Haydar Yalcin a, Tugrul U. Daim point out that the emergence of new technologies, the development of Industry 4.0 and artificial intelligence are changing not only technology, but also the ways of doing business and the life of society as a whole [1]. Gregory Vial in his fundamental study conducts a semantic analysis and gives a definition of digitalization, as well as identifies the blocks of

* Corresponding author: Moonlight34@ya.ru

the digitalization process [2]. Among these blocks, the author includes structural transformations, changes in customer value, strategic decisions, assessment of positive and negative consequences of the introduction of new technologies. Thus, the complex impact of new technologies on the economy and society, the formation of value for the consumer, organizational and production structures, approaches to planning and management is emphasized. This causes the need to develop methods of economic evaluation of the application of digital technologies in various industries. Also, researchers note the ambiguity of digitalization, highlighting its positive and negative socio-economic consequences.

The development of interconnected digital technologies in transportation causes the emergence of so-called intelligent transportation systems. The latter combine applied developments in the field of unmanned transportation, navigation and remote monitoring systems, road regulation algorithms, etc. It is important to note that an intelligent transportation system implies the generation of a synergistic effect of the joint application of the above-mentioned tools and corresponding institutional arrangements. It is important to note that an intelligent transportation system implies the generation of synergistic effect of the joint application of the above-mentioned tools and corresponding institutional changes in the transportation industry.

The possibilities of digitalization in transport systems are disclosed in Russian and foreign applied research. Thus, the global nature of digitalization is emphasized in their work Saks, N.V., Kazanskaya, L.F., & Egorov, Yu.V [3]. Meiqing Du, Jiankun Zhou, Anthony Chen, Heqing Tan [4] provide an assessment of the impact of collaborative consumption transport on the capacity of the street and road network. Gulvi, I. proposes an author's approach to economic evaluation of blockchain technology adoption in supply chains [5]. Zhuravleva, N.A., Poliak, M. reveal the possibilities of applying big data analysis technology to organize passenger flows in mixed transportation in agglomerations [6]. Chechenova L. consider installing cameras using the artificial intellect to shortening the time of operation [7]. Khattak A., Yangsheng J., Muneeb A. consider the application of simulation modeling in passenger transportation management [8]. Organizational and economic aspects of optimization of transport processes based on modeling methods are discussed in the following works [9-12].

2 Methodology

The following methods were used to achieve the research objective. The review of scientific publications on the research topic and the subsequent systematization of their results was applied to assess the dynamics of the use of methods and tools of simulation modeling in transport infrastructure management. The method of simulation modeling using AnyLogic training version was used to build models of passenger transport infrastructure objects and obtain results useful for forecasting and management decision-making. In addition, simulation modeling tools allowed us to systematize the effects of their application and adjust the methods of economic description of the use of this technology in the context of passenger transport system management. To build simulation models at different stages of the study, we used the methods of statistical observation, summary and grouping of the obtained data, and to assess the fluctuations of the studied parameters, we used the methods of calculating average values and variation indices.

3 Results

The review of the results of scientific publications and our own research allowed us to identify several main directions of simulation modeling application in passenger transport system management.

Identification of "bottlenecks" on the territory of a transport infrastructure facility (transport and transfer hub, service pavilion, waiting room) and consideration of options for their elimination. As an example, let's consider the model of the suburban train passenger service pavilion at the railway station. Empirical data on passenger flow during peak hours, the number of working ticket offices and the share of passengers purchasing tickets (other passengers had multiple-use travel documents) were collected for its construction. The model was built in the simulation environment of the training version of AnyLogic program using the discrete event modeling method. The results of the model run in the AnyLogic environment are presented in Figure 1.

Fig. 1 shows the model blocks and its parameters in the lower part, and the upper part shows the visualization of passenger movement from ticket offices to turnstiles. The color corresponds to the value of passenger flow density (the scale is presented on the right). It can be seen that critical density values, which correspond to the red color, are observed near the ticket offices located in the lower left corner of the pavilion scheme. This suggests the expediency of increasing the share of passengers with a single reusable ticket in order to unload ticket offices and eliminate the identified "bottleneck".

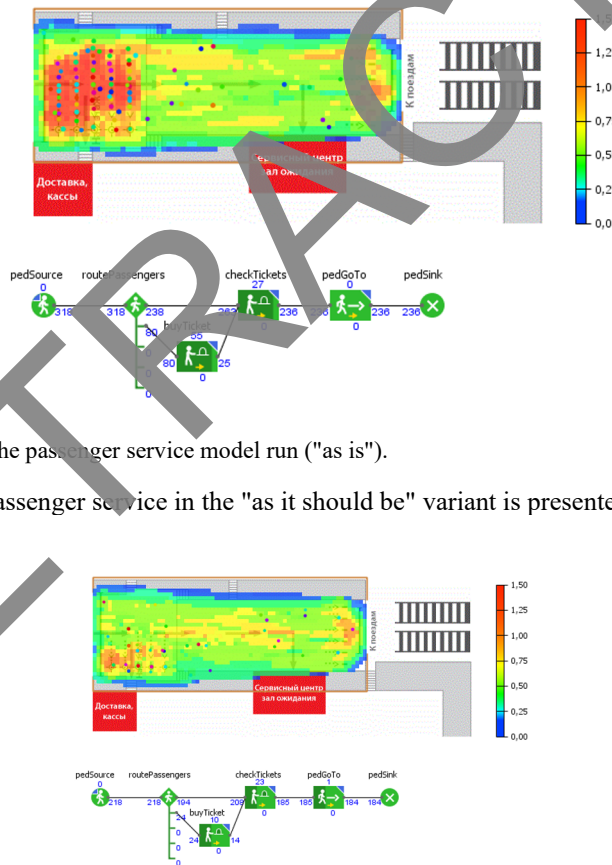


Fig. 1. Results of the passenger service model run ("as is").

Modeling of passenger service in the "as it should be" variant is presented in Fig. 2.

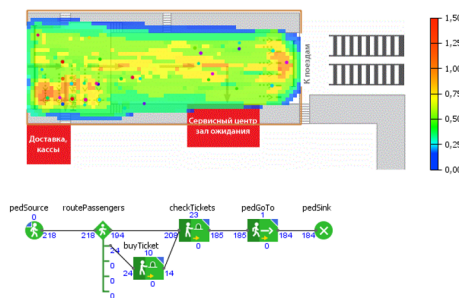


Fig. 2. Results of the passenger service model run ("as it should be").

It is possible to economically describe the results of the model operation by means of calculation of two effects - commercial for the company (reduction of labor costs for passenger service) and social for passengers (reduction of time costs).

2. Improving the efficiency of traffic regulation.

As an example, we present a model of intersection operation, the results of which are described in the paper [13]. The model reproduces the operation of one of the small intersections in St. Petersburg using a traffic signal algorithm based on queuing theory and data analysis of the number of cars in front of the traffic light. The algorithm itself (Fig. 3) and the intersection model were built in AnyLogic environment based on agent-based modeling technology.

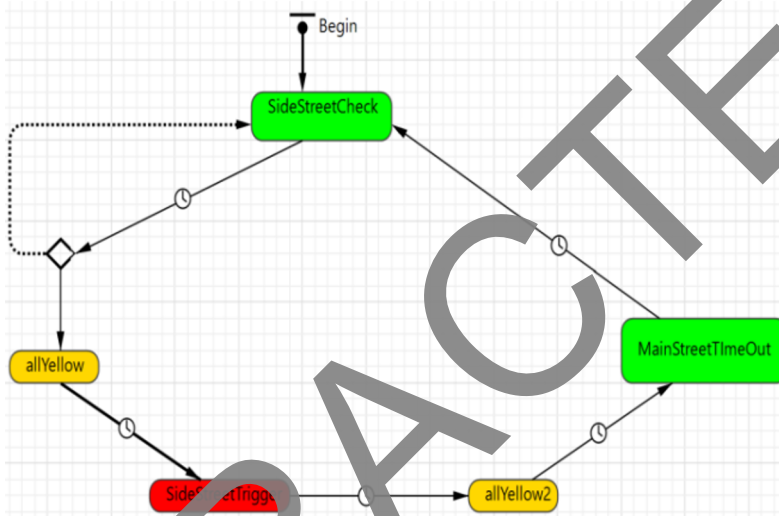


Fig. 3. Visualization of the algorithm of "smart" road regulation

It is possible to conduct economic assessment, describe the results of the algorithm and the model by calculating the social effect of reducing the time of waiting for cars in the queue at the intersection.

3. Assessing the implications of strategic decisions and the resources required.

As an example, we can consider a decision project on the introduction of a new public transportation route (in the model - electric bus) in one of the districts of St. Petersburg. To assess the future operation of the route and its impact on the transport situation in the district, a simulation model was built in AnyLogic environment using the discrete event simulation method and visualization of the model operation on the city map. A fragment of the model is presented in Fig. 4.

The model run allowed to conclude that at a given traffic intensity the demand for public transport transportation will be satisfied while maintaining comfort (vehicle cabin occupancy rate slightly above 50%). The maximum daily mileage of the vehicle was estimated and conclusions were made about its compliance with the requirements and technical characteristics of the electric bus. The model was used to determine the traffic interval during peak hours and the rest of the time of transport operation, as well as to estimate the need for a fleet of rolling stock on the route.



Fig. 4. Fragment of the model of operation of a new urban public transport route

4 Discussion

The development of ITS is associated not only with the possibility of using information tools in the transportation environment, but also with changes in the market conditions of transportation services [14].

From the users' point of view, an intelligent transport system is a unique set of information, service and transport services provided to passengers in order to achieve the highest possible efficiency of resource use. The final set of user services is formed taking into account the degree of development of transport infrastructure, available resources and specific goals regulated by the national strategy of transport industry development. The main social benefits arise from the creation of a transport information environment that reduces travel time. For example, increasing the capacity of the street and road network by automatically managing the transport system and optimizing the distribution of traffic flows taking into account the current state of traffic. Time savings are calculated on the basis of the total distance from origin to destination, so for a reliable assessment of time for multimodal trips, it is necessary to take into account not only the distance traveled by the main mode of transport, but also the other stages of travel [15].

An important condition for the formation of social effects is the need for timely informing the participants of the transportation process and the population about the organization of transport traffic, taking into account short-term forecasting. Short-term forecasting of the traffic situation allows passengers to choose the most optimal route using all types of transport involved in transportation. It is worth noting that the release of additional time from reducing the duration of trips can be considered as a factor in the growth of human capital, ensuring the growth of labor productivity, and as a consequence, the growth of real GDP.

Increase of transport and economic safety can be considered as a socio-economic effect arising due to prompt informing of transport traffic participants and special services. Automation of transport facilities management also reduces the probability of emergencies related to human factor. If we consider safety on passenger transport, this effect is achieved due to the presence of various devices that allow assessing risks - video cameras, smoke and temperature sensors, etc.

The economic effect is generated by increasing the mobility of citizens and optimizing the work of transport operators and institutions serving the urban environment. The implementation of ITS provides the growth of efficiency of the available resources use due

to the receipt of updated information that allows planning the work of municipal organizations. Since the formation of ITS contributes to the growth of mobility of the population, which affects the demand for passenger transportation services.

Environmental effects directly depend on the transport technologies on the basis of which transportation services are implemented. The use of environmentally friendly modes of transportation enhances the effect of reducing the environmental load.

5 Conclusion

Modern global transportation policy demonstrates a steady trend towards the development and implementation of intelligent transportation systems, which are simultaneously considered both as a method of transportation industry management and as a tool for solving the most urgent problems that reduce the pace of economic development. First of all, it is connected with the requirements of increasing transport safety, the need for rational use of available resources, the growth of population mobility and changing requirements of passengers to the quality of transport service. The article considers the potential of application of simulation modeling as a tool for transport system management, specifies the emerging effects of ITS implementation and proposes ways of economic evaluation of the observed effects.

References

1. Haydar Yalcin, Tugrul U. Daim, *Transportation Research Part E: Logistics and Transportation Review*, **168**, 2022, 102943, doi:10.1016/j.tre.2022.102943.
2. Gregory Vial. *The Journal of Strategic Information Systems*, **28**, 2, 2019, 118-144, doi:10.1016/j.jsis.2019.01.003.
3. Saks, N.V., Kazanskaya, L.F., Egorov, Ya.V.: *Digitalization is a factor in the formation of new economic opportunities under globalization conditions*. In: Proceedings of the 18th International Scientific Conference Globalization and Its Socio-economic Consequences. (Part V. Digital Single Market), pp. 2152–2158. (2018), doi:10.1051/shsconf/20196507004.
4. Mugging Du, Jiankun Zhou, Anthony Chen, Heqing Tan, *Transportation Research Part E: Logistics and Transportation Review*, **168**, 2022, 102937, doi:10.1016/j.tre.2022.102937.
5. Gulyi, I. *Economic assessment of the implementation of distributed data registry platforms in multimodal transport*. In: E3S Web of Conferences. Sustainable Energy Systems: Innovative Perspectives, SES 2020, p. 01068. (2020), doi:10.1051/e3sconf/202022001068
6. Zhuravieva, N.A., Poliak, M.: *The architecture of managing big data of mixed transportation of passengers in agglomerating glomerations*. In: Conference Series: Materials Science and Engineering." VIII International Scientific Conference Transport of Siberia 2020", 012055. (2020), doi: 10.1088/1757-899X/918/1/012055
7. Chechenova, L., *Artificial Intelligence as a Basic Resource of Modern Transport Infrastructure*. In International Scientific Siberian Transport Forum, 2023, p. 136-144. doi:10.1007/978-3-030-96380-4_16.
8. Khattak, A., Yangsheng, J., Abid, M. M. *Arabian Journal for Science and Engineering*, 2018, **43**, 5499-5516. doi:10.1007/s13369-018-3194-2

9. Zhu, Y., Hu, C., Xu, D., Tang, J., *Procedia-Social and Behavioral Sciences*, 2014, **138**, 776-782. doi:10.1016/j.sbspro.2014.07.258.
10. Valeev, S., Kondratyeva, N. *Infrastructure object management in the conditions of critical situations based on situational models*. Tenth International Conference Management of Large-Scale System Development, 2017, p. 1-5, doi: 10.1109/MLSD.2017.8109701.
11. Krasnikov A., Nikishina I., Laamarti Y., Voronin I., Okhotnikov I., Litvin I. *E3S Web Conf.*, 2022, Vol. **363**, p. 02037. doi: 10.1051/e3sconf/202236302037.
12. Korotun, O., Kolodochkin, A., Laamarti, Y., Assylbayev, A. *BIO Web of Conferences*, 2024, **83**, p. 05006. doi/10.1051/bioconf/20248305006
13. Zhuravleva N., Volkova E., Solovyev D. *Smart technology implementation for road traffic management*. *E3S Web of Conferences.* "Sustainable Energy Systems Innovative Perspectives, SES 2020", 01063. (2020), doi:10.1051/e3sconf/202022001063
14. Lyakina, M., Sheehy, M., Podhorska, I.: *Geopolitics, History, and International Relations*, **11**, 62-68. (2019), doi:10.22381/GHIR11220199
15. Romanov, A., *E3S Web of Conferences*, 2023, vol. **363**. doi:10.1051/e3sconf/202338303003.