Simulation modelling of traffic flow of the east-west latitudinal corridor for socio-economic development of the Novosibirsk region

Aleksander Krasnikov[1,*], *Irina* Nikishina[2], *Olga* Mudrakova[3], and *Igor* Krasilnikov[4]

[1]Academy of the State Fire Service of the Ministry of the Russian Federation for Civil Defense, Emergencies and Elimination of Consequences of Natural Disasters, Moscow, Russia
[2]Moscow Polytechnic University, Moscow, Russia
[3]Russian State Social University, Moscow, Russia
[4]Mendeleyev University of Chemical Technology of Russia, Moscow, Russia

Abstract. The article presents the study's results to assess the degree of impact of different categories of objects on traffic flows in the city of Novosibirsk (Russia). The main feature of the area is its intersection with the Trans-Siberian Railway. The highway is a transport corridor linking states in the European part of the continent with the countries of the Asia-Pacific region. Using structurization, analysis, synthesis, and simulation modeling allowed us to obtain a quantitative and qualitative description of the key objects whose behavior significantly affects the implementation of traffic flows in the study area. Formal rail, road, and pedestrian behavior models are studied and presented. Such models became the basis of simulation modeling, allowing us to estimate the degree of influence of modernization of the Trans-Siberian Railway and the objects of street road infrastructure of Novosibirsk adjacent to the relevant sections of the railway.

1 Introduction

The concept of the modern city involves its transformation into a complex, intelligent system that uses the full potential of information technology to improve citizens' quality of life through the analysis of large flows of information data [1]. As a complex organism, any city has socio-economic, environmental, transport, and urban development problems. The most pressing problem for modern large Russian cities is the problem of overloading road infrastructure. More often than not, such overloading is due to the historical layout and development and an increase in personal and commercial motor vehicles.

The modern economic development of Russia involves the active implementation of the concepts of development of the regions of the Far East and developed economic integration with the countries of the Asia-Pacific region [2]. All this implies the modernization and scaling of the transport system in this direction. The increase in freight rail traffic changes

* Corresponding author: askrasnikov@gmail.com

the familiar face of cities, as it requires the construction of supporting infrastructure to match the volume of production (e.g., railway yards, additional tracks).

Solving such problems requires analyzing a large amount of heterogeneous data, taking into account the variability of the situation, operational management, and forecasting. As noted by researchers in their works, the optimal tool for solving such problems is the creation of simulation models of transport systems [1-4].

Thus, the **study** aims to assess traffic flows on the section of the latitudinal corridor "east-west" in the city of Novosibirsk. The study's primary objectives include the analysis of the street road network of the area through which the section of the Trans-Siberian Railway passes, obtaining qualitative and quantitative characteristics of the selected section, and, based on such data, obtaining a simulation model of objects involved in transport processes.

The theoretical implication of the study is to obtain the parameters of the street road network of the district, affecting the state of the traffic of vehicles, and the development of a universal model of traffic flows.

The practical implication of the study lies in using the developed model in the planning and implementing urban planning policy of the city, management of urban systems in real-time and decision support.

2 Materials and methods

The object of the study is a section of the street road network of the Leninsky district of Novosibirsk, the scheme of which is shown in Figure 1.

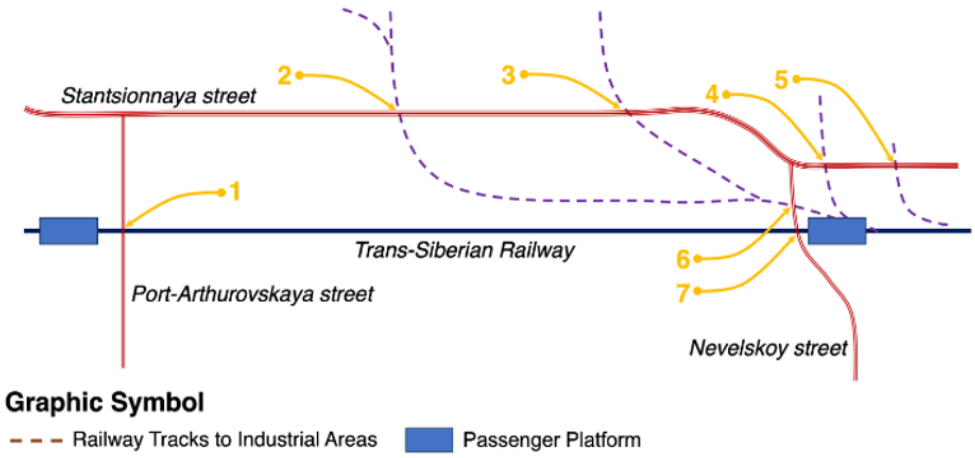


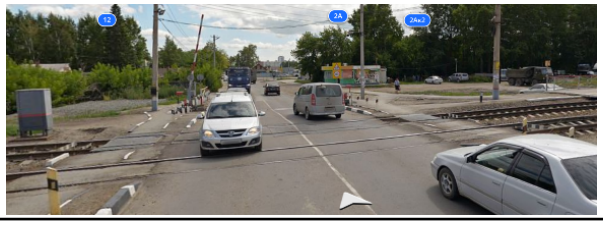
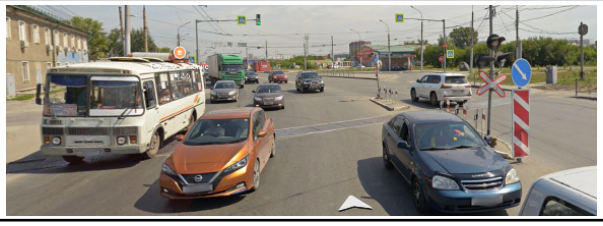
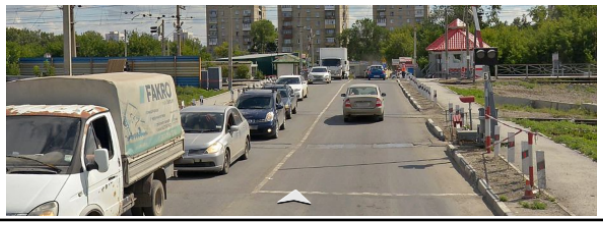
Fig. 1. Scheme of the study area of the Leninsky district of Novosibirsk (Russia).

The study area includes the following objects:

- station street from the intersection with Port Arthur Street to Nevelskogo Street;
- section of the Trans-Siberian Railway from the Ippodrom platform to the Zapadnaya Ploshchadka platform;
- accesses to the intersection of the Trans-Siberian Railway by Port-Arturovskaya and Nevelskogo Streets.

Table 1 shows the railroad crossings related to the object of the study and marked by numbers in Figure 1.

Table 1. Images of railroad crossings of the research object.

No.	Graphic image
1	
2	
3	
4	
5	
6	

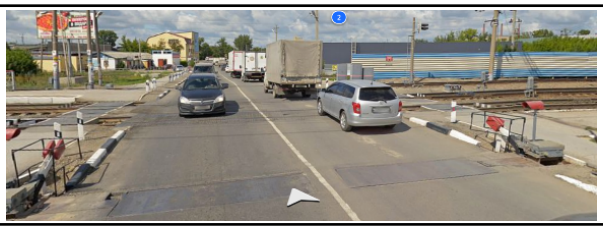
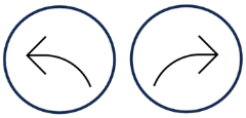
7	

Image Source: Yandex-Panorama https://yandex.ru/maps/-/CCUwQFCfXC

A set of general scientific methods was consistently used to obtain a simulation model of the street road network object. The composition of such a complex includes:

1. *Structuring method*. As Logachev [5], Kabulov [6], and Volobuev [7] note in their studies, the use of such a method allows to establish qualitative and quantitative characteristics of the study object.
2. *The method of synthesis* and *analysis* establishes the essential connections between processes and subjects necessary to create a formal model [3, 8, 9].
3. *Simulation modeling method* that allows to get a model from entities that have a certain activity. In addition, such entities have autonomous behavior, deciding according to some rules, interacting with the environment (including other entities), and changing [5, 9]. The states of entities determine the basis of such a simulation model, the key elements of which are presented in Table 2.

Table 2. States of entities of the research object.

No.	Graphic designation	Characteristic
1		Beginning and end of the traffic flow
2		A place where traffic flows merge or separate (corresponds to the intersection of any road network)
3		Agents turn left and right, respectively
4		Crossing a railway crossing equipped with light and sound signaling devices
5		Movement of agents in the traffic flow from one decision-making place to the next
6		Crossing of traffic and pedestrian flows at a regulated crossing

7		Stopping traffic flow at a traffic light
8		Stopping the traffic flow when boarding or deboarding passengers of public transport at a bus stop

Using models based on the states of entities allows us to get an idea of the general behavior of the system depending on changes in its parameters.

3 Results

Using the stated research methods allowed us to establish all the key elements of the study object. It was found that difficulties in the movement of road transport are observed at railway crossings (Figure 2).

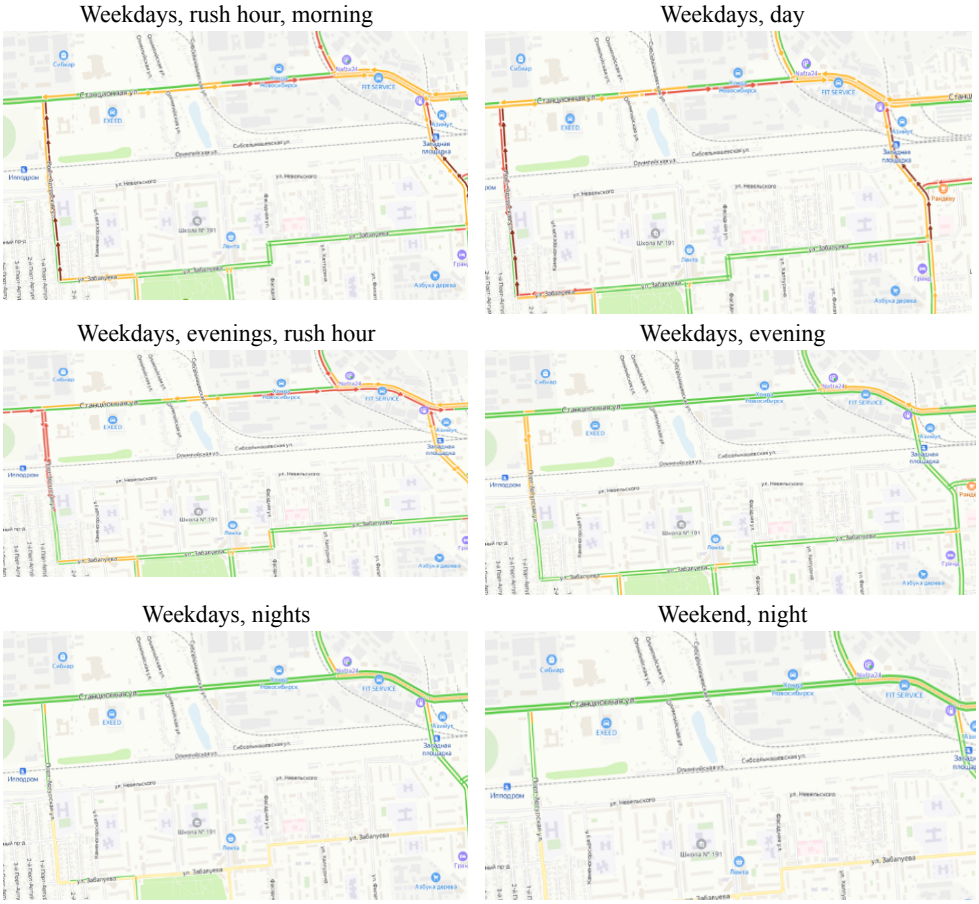


Fig. 2. Traffic congestion of the object of study (*Image source*: Yandex-Traffic Jams https://yandex.ru/maps/65/novosibirsk/probki).

The following conclusions were made while analyzing the data obtained on traffic congestion:

1. Car traffic increases significantly in the periods of an hour before the start and an hour after the end of the work day.
2. Significant difficulties in the movement of road transport are observed at railway crossings. This is due to a reduction in speed to cross the railroad tracks.
3. Stopping road traffic at the railway crossings of the main course of the Trans-Siberian Railway. This is because there are commuter rail stations near the railroad crossings. Suburban trains increase or decrease their speed, which increases the time of their passage through the railway crossing. According to the schedule of suburban electric passenger trains, 19 pairs of trains pass on this section daily, and 32 pairs of long-distance passenger trains. At the same time, the movement of freight trains is not excluded at this site.

Motor vehicles were used as entities for the simulation method. Classification of vehicles was not made, that is, the behavior of a truck is similar to that of a passenger vehicle. Using graphic elements from Table 2 allows us to develop standard scenarios for the behavior of all entities in the given areas of the object of research. Such scenarios describe state diagrams of entities when a vehicle moves on certain roads:

1. Nevelskogo Street from Stantsionnaya Street (near the Western Platform platform) – Figure 3.

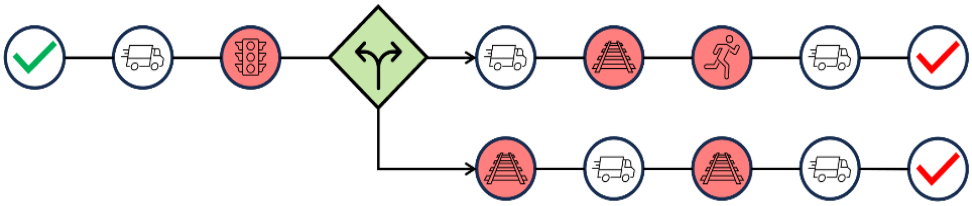
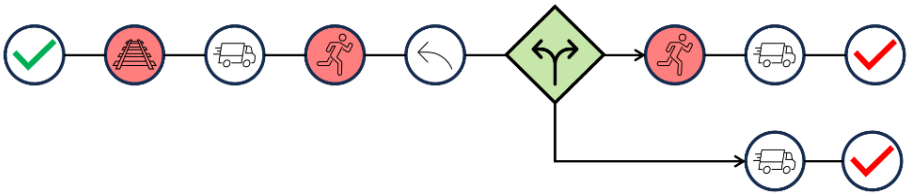


Fig. 3. Model of traffic states along Nevelskogo Street (Novosibirsk, Russia).

2. Port-Arturovskaya Street from Stantsionnaya Street (right turn – Figure 4a, left turn – Figure 4b) to the railway crossing near the Ippodrom platform – Figure 4.

a)



b)

Fig. 4. Model of traffic conditions along Port-Arturovskaya Street from Stantsionnaya Street to Ippodrom platform (Novosibirsk, Russia).

3. Port-Arturovskaya Street from the railway crossing at the Ippodrom platform to Zabalueva Street – Figure 5.

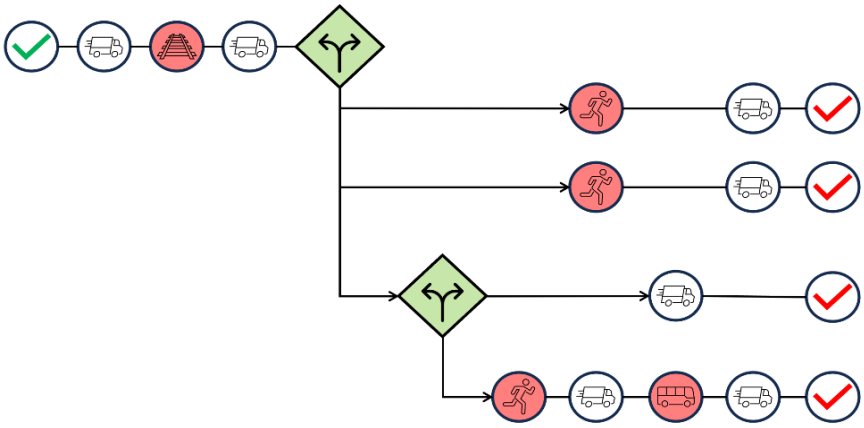


Fig. 5. Model of traffic conditions along Port-Arturovskaya Street from the Ippodrom platform to Zabalueva Street (Novosibirsk, Russia).

4. Port-Arturovskaya Street from Zabalueva Street to the railway crossing at the Ippodrom platform – Figure 6.

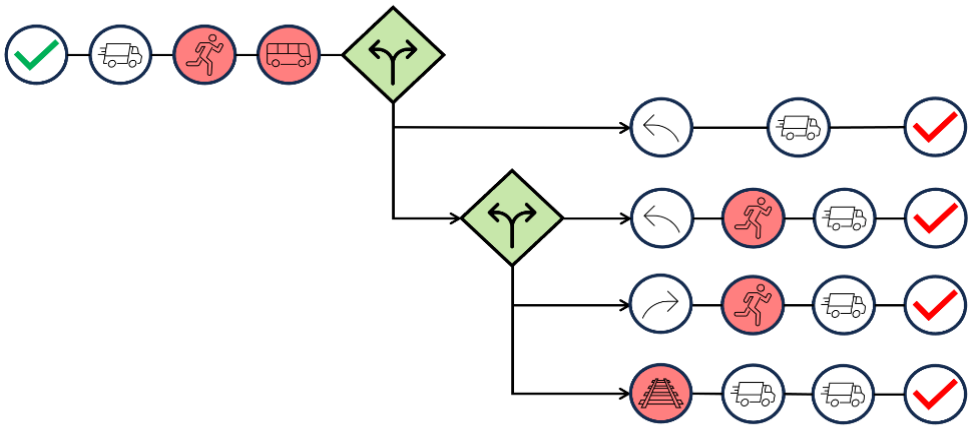


Fig. 6. Model of traffic conditions along Port-Arturovskaya Street from Zabalueva Street to Ippodrom platform (Novosibirsk, Russia).

The following rules were adopted in the development of motion state diagrams:

1. The beginning of the movement of a vehicle on a specified section is considered to be its entry into the road in question. The object's behavior up to this point does not affect the character of the movement, so it is not considered.
2. Completing the vehicle's movement in the specified area is considered its departure from the object of study. The nature of the further behavior of such a vehicle (will make a stop, exit to the yard area, turn to another street, etc.) does not affect the behavior of the entities of the object of study.
3. One model is created if the traffic on the same street is similar in different directions. Thus, motion in the opposite direction corresponds to a mirror image of the model.

Analysis of the results showed that the "problem areas" of the street road network are railroad crossings. They significantly reduce the capacity of roads due to the need to reduce

vehicle speed when crossing the tracks and stopping traffic when trains are moving. The solution to the problem is the construction of bridge crossings along the streets of Port-Arturovskaya and Nevelskogo. This will not only increase the capacity of these sections but will also provide a high level of connectivity of areas of the city separated by the railroad and increase the level of traffic safety, as it will exclude the possibility of collision of road vehicles with railway transport.

4 Discussion

The growth of large cities and agglomerations presents planners and municipalities with some challenges regarding searching for optimal urban planning regulation strategies [1]. As noted by scientists in their works, methods and means of simulation modeling allow finding the best scenario for sustainable development of the city, taking into account the economic and environmental components [3, 10, 11].

The developed models demonstrate the constraint of urban development due to the disconnection of city sections by the railroad with heavy rail traffic. The resulting formal models allow studying the behavior of entities in traffic flows following the strategic development of both urban infrastructure and the railway corridor [12-14]. This means that it is possible to visualize and assess the effects of increasing the number of train pairs passing on a given section relative to the traffic flow crossing the railroad tracks, replacing railroad crossings with bridge crossings, or widening the roadway.

5 Conclusion

Russia's national project, "Comprehensive plan for the modernization and expansion of the mainline infrastructure", suggests increasing the capacity of the Trans-Siberian railway by 1.5 times. This will reduce the delivery time of transit containerized cargo in the east-west latitudinal corridor to seven days. All this increases the load on the existing railway infrastructure but also significantly impacts the street road network of the cities through which it passes or bypasses.

The developed models allow different simulation scenarios to evaluate the interaction of agents of three types: road vehicles, railway trains, and pedestrians. At the same time, it is possible to assess the degree of influence of the behavior of such agents on the relevant infrastructure for sustainable development of urban and adjacent territories following the implemented concept.

References

1. A.F. Ageeva, Elect. Inf. Sys. **3(26)**, 37-53 (2020)
2. S. Yansong, P.K. Njoroge, V.D. Chernikova, S.V. Trukhanov, D.M. Kasumova, Yu.A. Laamarti E3S WoC **403**, 08013 (2023) https://doi.org/10.1051/e3sconf/202340308013
3. M. Logachev, A. Tkachev, I. Nikishina, E3S WoC **363**, 02036 (2022) https://doi.org/10.1051/e3sconf/202236302036
4. N.N. Pluzhnikova, Transp. Res. Proc. **68**, 34-39 (2023) https://doi.org/10.1016/j.trpro.2023.02.005
5. M. Logachev, V. Bugrimov, A. Kondrat'ev, Transp. Res. Proc. **63**, 2335-2340 (2022) https://doi.org/10.1016/j.trpro.2022.06.267
6. A. Kabulov, I. Kalandarov, I. Saymanov, Transp. Res. Proc. **63**, 108-118 (2022) https://doi.org/10.1016/j.trpro.2022.05.013

7. A.O. Volobuev, Imitation modeling at the optimization of transport networks, Youth. Society. Modern Science, Technology and Innovation, 19, 259-261 (2020)
8. M. Logachev, V. Chernova, Y. Laamarti, T. Makhamatov, V. Ivlev, L. Giulodori, I. Tutkova, Int. J. Inst. **15(3)**, 153-170 (2022) https://doi.org/10.29333/iji.2022.1539a
9. M. Logachev, V. Chernova, V. Kovaleva, *Information system for the creation and support of the ecological settlements' framework*, in AIP Conference Proceedings, **2560**, 020013 (2023) https://doi.org/10.1063/5.0124704
10. D. Lazarenko, V. Nagorny, Transp. Res. Proc. **63**, 154-159 (2022) https://doi.org/10.1016/j.trpro.2022.05.018
11. A. A. Izyumsky, S.L. Nadiryan, I.S. Senin, Polytech. Bul. **1**, 52-54 (2016)
12. A. V. Sugorovsky, Innov. Transp. Sys. Tech. **8(1)**, 115-123 (2022) https://doi.org/10.17816/transsyst20228196-104
13. P. A. Kozlov, O.V. Osokin, V.S. Kolokolnikov, Railway Transp. **6**, 12-16 (2018)
14. M. Logachev, E. Tolkacheva, S. Shibaev, V. Chernova, A. Butyrin, E3S WoC **403**, 07011 (2023) https://doi.org/10.1051/e3sconf/202340307011