Transport Planning of a Metropolis Street Using Simulation Modeling

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Abstract. This article presents a plan for the development of the area adjacent to Pryanishnikov Street in the Timiryazevsky District of the Northern Administrative District of Moscow. This plan involves upgrading the roadway to distribute traffic flows and isolate the public transport flow. Simulation models are created, reflecting all the objects and rules of interaction that are typical for the studied area to assess the effectiveness of the developed concept. The main feature of the site development plan is the safety of all road users, reducing the downtime of personal road and public transport to increase the capacity of the road network and improve the environmental condition of the area. The created scheme and traffic models are the basis for the urban city development plan and can be used to simulate different scenarios of territory changes and operational management of traffic and pedestrian flows.

1 Introduction

The transport layout of the streets of any city (especially a metropolis) takes place in the context of the historically established development. As Petrushina says in her study [1], in most cases the already established structure of urban roads does not meet modern requirements (e.g., road capacity). Transport accessibility in cities should be ensured by organizing intracity traffic along coordinated transport corridors. Traffic coordination should be based on the regulation of the speed mode of traffic flows depending on a load of regulated intersections, the length of legs, and the composition of the flow [1, 2]. It should take into account the presence of public transport flows, which are most often part of the overall traffic flow (e.g., there are no dedicated lanes for public transport, allowed left turns that intersect with streetcar traffic, etc.).

When drawing up a traffic plan and schedule, a large amount of data must be processed, which includes the characteristics of traffic flows depending on the time of day and day of the week, the availability of road infrastructure and the possibility of its change, pedestrian flows, etc. For this purpose, simulation models are built to implement various load scenarios for the street road network. Many domestic and foreign scientists in their works (e.g.,

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Solovyov [3], Logachev [4], Tebenkov [2], Fontes [5], Kubek [6]) have noted that simulation models allow exact solving the problems of traffic optimization in an urban environment, organizing the topology of the transport network that allows predicting various situational tasks. The use of simulation models is justified by the randomness of the processes of pedestrian traffic in a given area, the directional movement of traffic flows of different types of transport, as well as the need to develop and evaluate the analytical apparatus for all emerging conflicting flows.

Thus, the purpose of the study is to increase the capacity of the road network for the safety of all road users.

The theoretical implication of the study is to formalize the objects of the street road network to be used in various studies related to the improvement of the area, ensuring its environmental well-being, sustainable development, rapid assessment of solutions to organize the traffic of different streams, etc.

The practical implication of the study is to create an adequate and reliable model of traffic flows for the planning of the section of the street road network of a metropolis. Certain provisions of the study can be used in the creation of a neighborhood improvement plan or the implementation of the urban planning policy of the city.

2 Objects and methods

The object of the study is the traffic flows carried out on the section of Pryanishnikov Street from Bolshaya Akademicheskaya Street to Timiryazevskaya Street in the Timiryazevsky District of the Northern Administrative District of Moscow. The peculiarity of the object of research is the presence of a streetcar line running along the middle of the roadbed. In the implementation of the transport layout, the physical limitations of this site should be taken into account, as the southern part of it is limited to the pond.

The following general scientific methods were used to create a transport layout project for the study area:

1. The structuring method allows highlighting the key objects and subjects of the problem area. As Logachev [7] and Kulibaba [8] note in their works, simulation models require input parameters that are derived from such a method.

2. The synthesis method allowed grouping of logically related objects to establish a set of rules used in simulation models. Analyzing the works of researchers in the field of simulation modeling, it should be noted that this method is used by them constantly and allows to obtain accurate results, adequate to the real world [9].

3. The analysis method in the study allowed to form a list of qualitative characteristics of the objects of the subject area. The design and development of a programmable object require such characteristics to verify the final result. A similar statement is reflected in Logachev [10, 11] and Soliño [12].

4. The graphical method allowed obtaining visual schemes of real objects of the subject area. This is necessary to visualize the key features during the study to adjust the parameters of the simulation model [13, 14].

5. The agent-based modeling method allowed to demonstrate the behavior of objects in the subject area when the rules of external or internal influence are changed. Studies by Kulibaba [8] and Logachev [4] note that the behavior of individual objects characterizes and determines the behavior of the whole system. This allows determining scenarios for sustainable development of the area, its ecological state, and other parameters determined over a long-time interval.


3 Results

The basis of the transport layout of the street road network section includes the organization of boarding and disembarking of passengers of public transport to improve traffic safety, reduce the number of stops for personal motor transport and increase the capacity of Pryanishnikov Street in the allocated section. In Figure 1, the streetcar and bus stop area are highlighted in red.

![Location of the research object on the map of Moscow](https://yandex.ru/maps/-/CCUSnFhD3B)

**Fig. 1.** Location of the research object on the map of Moscow

*(Background image source: Yandex maps [https://yandex.ru/maps/-/CCUSnFDtKA]*)

The peculiarity of stops on the dedicated road section is the allocation of the stopping area of the streetcar and bus moving in the same direction. In this case, the stops for the same type of public transport are not combined when moving in opposite directions. Figure 2 shows the bus stop when moving toward Timiryazevskaya Street (right lane) and the streetcar stop when moving toward Bolshaya Akademicheskaya Street (left lane).

![Public transport stop zones in opposite directions on Pryanishnikov Street in Moscow](https://yandex.ru/maps/-/CCUSnFhD3B)

**Fig. 2.** Public transport stop zones in opposite directions on Pryanishnikov Street in Moscow

*(Source: Yandex-Panorama [https://yandex.ru/maps/-/CCUSnFhD3B]*)

It should be noted that streetcar passengers are disembarking and boarding on the roadway. This stops traffic in the single lane when the streetcar stops. At the same time on the opposite side when stopping the bus also blocks the movement of personal motor vehicles or provokes the situation of the traffic flow to the streetcar tracks. A similar situation arises in the opposite direction.

An additional restriction to the traffic flow of cars moving in the direction of Bolshaya Akademicheskaya Street is the Pryanishnikov Street exit (Figure 3). According to traffic rules, this exit can be used by vehicles making a left turn from Pryanishnikov Street, and a right turn – when moving from Timiryazevskaya Street. Such an exit is equipped with an
unregulated crosswalk, which creates an additional stop for all road users when a pedestrian appears on this section of the road.

![Unregulated Crosswalk Image]

**Fig. 3.** exit from Pryanishnikov Street to Bolshaya Akademicheskaya Street in Moscow  
(Source: Yandex-Panorama https://yandex.ru/maps/-/CCUSnJUWC8)

The result of using a combination of methods of structurization, synthesis, analysis, and graphical method is a scheme of traffic and pedestrian flows on the studied section of the street road network (Figure 4).

![Traffic and Pedestrian Flows Scheme]

**Fig. 4.** Scheme of transport and pedestrian flows on Pryanishnikov Street in Moscow

**Graphic Notation**
- Green arrow: direction of transport flow
- Blue arrow: direction of pedestrian flow
- White area: pedestrian crossing
- Purple area: bus waiting area
- Light yellow area: passenger boarding and disembarkation area
- Grey area: sidewalk
- Pink area: tram waiting area
Based on the obtained scheme, a simulation data flow diagram is created using synthesis and agent-based modeling methods (Figure 5). The elements of such a diagram are states in which there is a set of agents with the same type of behavior. To simplify the perception of the diagram, state designations using road signs are used.

![Diagram of traffic flows simulation model of a section of Pryanishnikov Street in Moscow](image)

Fig. 5. Diagram of traffic flows simulation model of a section of Pryanishnikov Street in Moscow

Analyzing the traffic pattern (Figure 4) and the agent-flow model (Fig. 5), the team of authors concludes that this section of the road has difficulties in the movement of road transport due to the large number of states that lead to its stoppage. So, when driving towards Timiryazevskaya Street, cars will have to stop when boarding and disembarking streetcar passengers, let pedestrians pass at a crosswalk, stop next to a car making a left turn at the exit, and stop when boarding and disembarking bus passengers. The presence of an unregulated crosswalk over the exit also creates problems for all road users, as the pedestrian has priority in their movement. Thus, cars exiting from Pryanishnikov Street when driving to Bolshaya Akademicheskaya Street, letting a pedestrian through, obstruct the movement of other participants going straight ahead. At the same time, cars making a left turn on the way to the exit obstruct the movement of road transport and streetcars in the direction of Timiryazevskaya Street. A simulation model simulating traffic scenarios on this section of the street road network shows that traffic is hampered during weekday peak hours.

The solution is to combine stops for different types of public transport in a separate traffic lane with a transfer behind the exit to the Moscow Polytechnic University (the green area in Figure 1). Figure 6 shows the location of the stop areas, which is the basis for a simulation model that simulates the effects of the proposed changes.
The stopping point must be located on platforms facing each other, as shown in Figure 7.

Each platform must be equipped with a sloping descent to a regulated crosswalk. Such a crosswalk should be located on the side of Bolshaya Akademicheskaya Street. The crosswalk will be used by pedestrians going to Moscow Polytechnic University and the Russian Agrarian University.

The length of the platform must be at least 30 m since the length of the streetcars running on this section is 16.7 m (model 71-911M “Lvenok”) and 27.5 m (model “Vityaz-M”). The platform can simultaneously be used for boarding and disembarking passengers not only by streetcar but also by bus. The dimensions of the vehicles used allow for this. The width of the streetcar (regardless of model) is 2.5 m, and the bus models used on the routes – 2.5 m (model LiAZ-5292.71). The length of the rolling stock of buses: up to 12.4 m.

To embed platforms in the study area will need to narrow the lane for road transport up to 3 m and move it 1 m towards the sidewalk. There are such resources for the location of the car lane and sidewalk for pedestrians in the specified area. The organization of transport and pedestrian flows in this case should be carried out according to the scheme shown in Figure 8.
Based on the obtained scheme of the territory development, a simulation model was built, which is based on a flow diagram (Figure 9).

**Fig. 8.** Scheme of transport and pedestrian flows in the development of Pryanishnikov Street in Moscow

Traffic flows simulation in the organization of traffic shown in the diagram in Figure 8, showed that the downtime of all modes of transport decreased. This is due to the fact that the number of events arising from stops of each mode of transport has been reduced.

4 Discussion
The organization of change in the urban environment or any particular area requires obtaining all the objects and actors involved in its processes. Based on such results, the rules of interaction between objects, as well as the rules of external influence are compiled. As Kulibaba [8], Logachev [4], Soliño [12], and Fontes [5] all note in their works, these are fundamental to creating simulation models of a real object. As a result of the study, the team of authors obtained such objects and their characteristics.

Based on this was created the concept of the organization of traffic flows. The team of authors believes in separating the public transport flow and the personal road transport flow. Researchers Belov [14], Petrushina [1], and Kubek [6] believe that this will not only increase the capacity of the entire section but also increase the safety of every road user, including pedestrians. This is confirmed in the results of our study. Thus, the simulation model, which includes the planned changes, showed that the number of stops for personal vehicular transport was reduced, and pedestrian flows were streamlined in relation to the places of their attraction (public transport stops, destinations for the path of travel, crosswalks).

5 Conclusion

Traffic and pedestrian flows actively impact the environment. No other city in the world has solved such an environmental problem. The development of the urban environment, taking into account the dense infill development (including historical) is a complex task. Changing any objects in the street road network immediately or over time affects the ecosystem of the entire site and its surrounding areas.

Thus, the decision to change must be thoughtful and weighted not only in the short term but also in the long term. All this is possible through the creation and use of simulation models. Such models reflect all aspects of the real object of study and allow recreating any conditions to assess the consequences of the behavior of such an object.

The study developed a concept for the development of the city territory with the creation of a simulation model. Based on the obtained simulation model, conclusions on the changes in the state of all objects of the street road network were made. All results are valid because general scientific methods were used to obtain them. They can be used by landscaping and development specialists, researchers who predict environmental changes based on the internal and external characteristics of the object of study.

References

2. S.E. Tebenkov, Development of methods for monitoring traffic flows for operational traffic management on highways. Author’s abstract (Irkutsk, 2013)
3. V.A. Soloviev, Modeling and optimization of traffic control in the network of a large city. Author’s abstract (Tyumen, 2013)


9. A.N. Novikov, A.G. Shevtsova, Safe and effective management of traffic flows in the urban transport system. Monograph. (Academy, Moscow, 2022)


14. A.V. Belov, Improving the efficiency of street and road networks based on controlling the formation of traffic flows. Dissertation (Saint Petersburg, 2014)