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Methodology for Providing Priority to Urban Passenger Transport Traffic

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ABSTRACT

The article considers the efficiency of providing priority conditions for urban passenger transport by allocating separate lanes for public transport on the roadway. The results of modelling the traffic flow on the considered segments of the city street network are complemented by a conclusion about the need to improve road traffic management on these segments, considering the intensity and composition of the traffic flow.

Simulation allows creating mathematical or computer models for analysing and assessing the traffic conditions of urban passenger transport. The models are based on various parameters of traffic flows, the schedule of urban passenger transport, the location of public transport stops, etc. Modelling allows conduct of different experiments to assess the effectiveness of various measures and changes in the transport system.

The objective of the study is to develop a methodology for analysing traffic conditions that will identify and assign priority to urban passenger transport traffic to achieve efficiency and comfort of its operation, improve transport accessibility and reduce traffic delays.

Optimisation of the traffic provides for various management scenarios to find optimal solutions that reduce delays, congestion, traffic intensity, etc.

Route planning is necessary for developing an optimal strategy for efficient passenger service. Demand forecasts make it possible to predict not only passenger traffic, but also the need for transportation in different periods, which is necessary for route planning and selection of optimal rolling stock features. All these areas of modelling the urban passenger transport traffic are developed to achieve the goals of increasing efficiency, reducing the risk of road traffic accidents, improving the quality of transport services and the safety of passenger transportation, which should create a sustainable system aimed at satisfying the basic needs of urban transport passengers.

Keywords: urban passenger transport, street, traffic flow, intensity, model, traffic, efficiency

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BACKGROUND

Road traffic management is relevant for the cities all over the world. Large and medium-sized cities in developing countries are currently at a stage of development when the transport component is evolving, and accordingly, problems associated with intensive transport development of cities become increasingly evident. Such problems include the level of traffic congestion on the street-and-road network, the quality of transport services, transport ecology problems, and road traffic safety. If in developed cities there is a trend to displace private cars from city centres and switch to public and environmentally friendly transport, which seemed impossible just a few years ago, then in developing cities problems of a different kind are growing: a low level of development, a slight increase in the standard of living, availability of credit products and, due to this, an increase in the purchasing power of the population and an increase in the level of motorisation.

At present, in large and largest cities, the most pressing transport problem is the discrepancy between the parameters of the street-and-road network and the level of motorisation. To improve the quality of transport services for the population and resolve conflicts in the urban transport system, it is necessary to develop and implement measures to popularise and increase the attractiveness of public urban passenger transport. To achieve this goal, it is necessary to increase the demand for fixed-route transportation, as an option, by improving the quality of transport services. One of the main criteria for assessing the efficiency of transport by users is the speed of travelling from origin to destination. And in this case, ensuring priority for ground public passenger transport is becoming increasingly important.

RESULTS

Dedicated lanes: Analysis of Problems and Approaches to Solve Them

«To ensure the efficient operation of the system providing for priority of fexed-route transportation, an effective method for calculating the efficiency of operation of the dedicated lane is required, considering the specified criteria and modelling the movement of traffic flows on segments of the street-and-road network. The direction of ensuring the priority traffic for urban passenger transport within the framework of optimising the operation of the transport system is actively implemented in European cities, as well as in the agglomerations of China, the USA» [1].

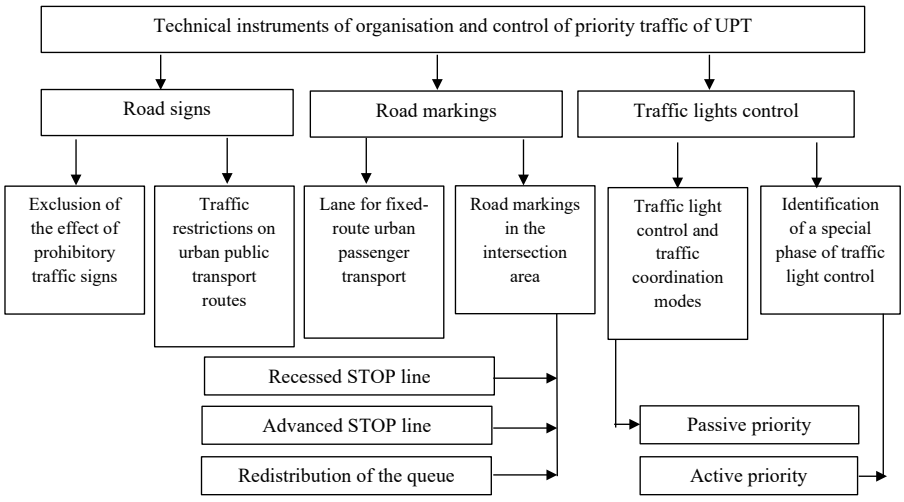
With the increase in the intensity of traffic flows, the task of ensuring the optimal speed mode and safety of fixed-route passenger transport (RPT) becomes especially urgent and at the same time difficult to solve. «Its solution requires providing certain advantages to public transport vehicles, which are provided by:

– regulatory documentation;

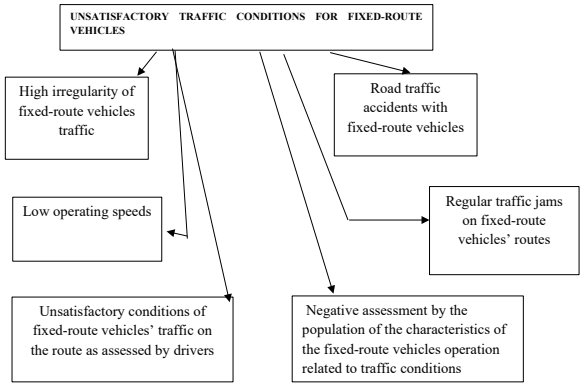
– road signs and traffic light control elements;

– ensuring the priority right of movement within the traffic light control cycle at intersections» [2];

– introducing some restrictions for other vehicles on the streets and roads along which urban passenger transport (UPT) routes pass;



Pic. 1. Technical instruments of ensuring the priority of fixed-route vehicles [performed by the authors].



Pic. 2. Traffic conditions of fixed-route vehicles necessary for introduction of priority traffic [performed by the authors].

– allocating a priority lane for fixed-route passenger transport.

The described methods are provided by the technical instruments shown in Pic. 1.

To increase the speed of urban route transport, it is possible to designate any street lane as a priority lane.

It is also possible to use tram stops for bus stops. In such cases, the landing platform and the stop pavilion are used jointly by passengers of both bus and tram routes.

If a decision is made to designate the rightmost lane of a city street as a priority lane for movement of RPT, then certain difficulties arise associated with the right turn manoeuvre: cars must change to the lane for RPT to perform the manoeuvre, and difficulties also arise with stopping and parking – other vehicles cannot stop in the lane for RPT.

«To determine the segments of the street-and-road network where it is necessary and appropriate to introduce the priority of RPT» [3], it is necessary to determine which traffic conditions of public transport within this segment are negative. This can be established by certain signs of unsatisfactory traffic conditions for RPT (Pic. 2).

«Currently, there are no criteria for introducing dedicated lanes for RPT» [4]. These measures are implemented chaotically, without considering the capacity of the roadway. The actual minimum capacity of a segment of the street-and-road network depends on the capacity of the «narrowest» segments, i.e. complex at-grade intersections with multi-phase traffic light control.

Accordingly, there is a need to develop a methodology for calculating the efficiency of a dedicated lane considering the specified criteria, modelling the movement of traffic flows on segments of the street-and-road network and determining the main stages of implementing the priority of urban passenger transport, which determines the relevance of this topic.

«To assess the possibility and efficiency of providing a priority lane for the RPT, it is possible to use the criterion of comparative transit capacity. If the value of this criterion exceeds one, then the introduction of priority can be considered effective and appropriate» [4].

$$K1 = \frac{(S1\varepsilon(n-1))}{(Q-q)}, \quad (1)$$

where S1 – capacity of one road lane, units/hour;

ε – coefficient of distribution of vehicles along the width of the roadway;

n – number of traffic lanes within the segment;

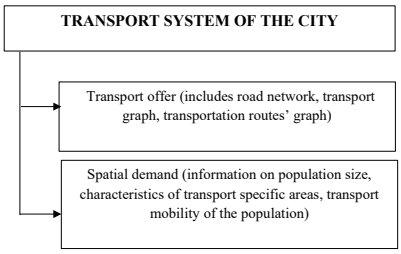
Q – traffic intensity within the segment, units/hour;

q – intensity of passenger transport traffic, units/hour [5].

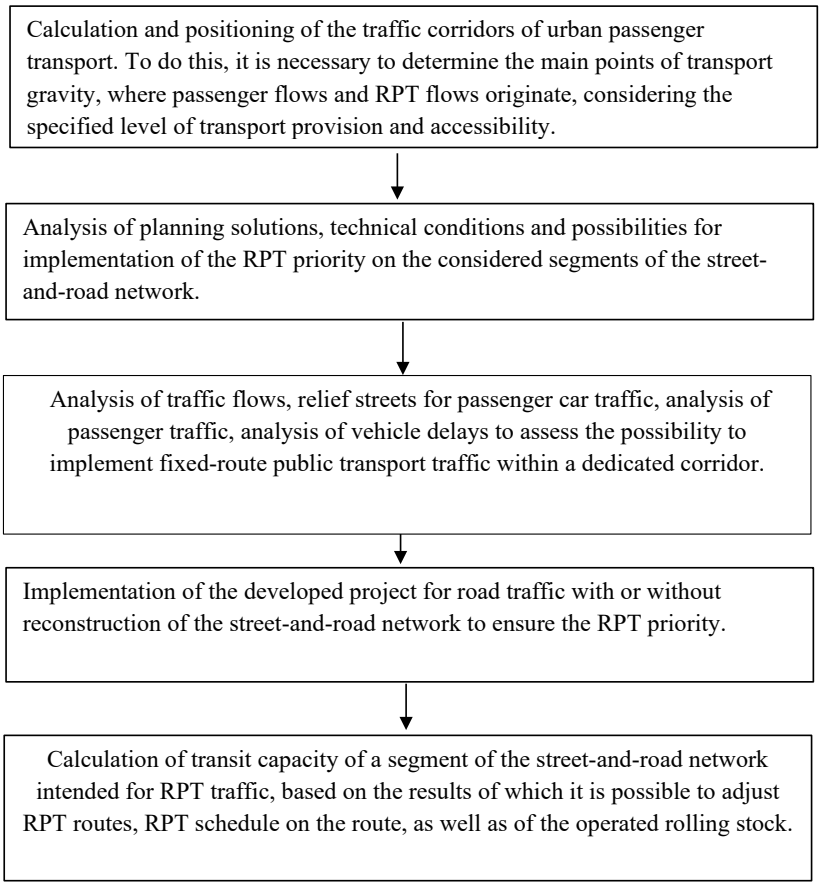
To decide on the necessity of introducing the priority of RPT traffic, it is mandatory to use the results of the survey of traffic conditions, traffic flow, and it is also necessary to consider the analysis of the effectiveness of the decision made, both from the technical and economic points of view.

«To assess the feasibility of introducing the priority right of movement of fixed-route passenger transport, such a criterion as a reduction in the time spent by road users on travel within the considered segment of the street-and-road network at a given occupancy rate of fixed-route passenger transport and passenger cars is used» [5].

«A computer model of the city's transport system using a software package allows for the calculation of passenger flows considering



Pic. 3. Model of the city's transport system [performed by the authors].



Pic. 4. The main stages of implementing the UPT priority [performed by the authors].

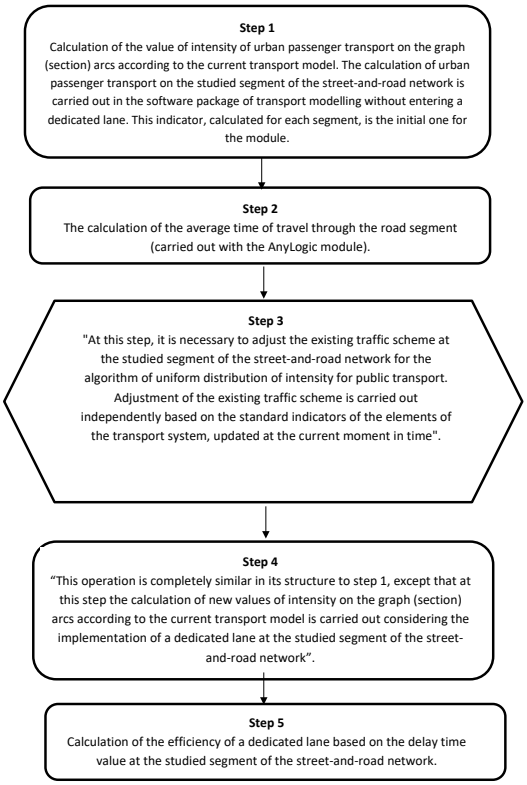
individual and public transport» [5]. «The model consists of two main parts» [6] (Pic. 3).

Determining the Optimal Variant of the Route Network of Urban Passenger Transport Based on Simulated Data and Expert Analysis

«To improve the structure of the route network of urban passenger transport, it is necessary to carry out preliminary modelling using mathematical tools, taking into account such indicators as the total travel time for «from door to door», the remoteness of stopping points, the traffic frequency of urban passenger transport, the number of transfers during a passenger trip, safety, the rate of occupancy of the rolling stock, the cost of travel, the convenience of using transport, etc.» [7].

The algorithm for implementing the priority of fixed-route passenger transport is shown in Pic. 4.

The data for the calculations were collected by field survey, by counting the number of vehicles passing through the road segment. Then, to simplify the calculations, the total intensity is reduced to that given by formula (2):



Pic. 5. Calculation of the efficiency of the dedicated lane [performed by the authors].

$$Nr = \sum_{i=1}^{n} (Ni \bullet Fr), \quad (2)$$

where *Ni* is traffic intensity of vehicles of this type, car/hour;

Fr – reduction factors for this group of cars [1].

To determine the advisability of granting UPT priority, it is necessary to implement a certain algorithm of actions [8], using the appropriate software (Pic. 5).

The study performed considered a segment of the street-and-road network of the Central District of the city of Krasnodar at the intersection of Ofitserskaya Street and Neftyanikov Highway.

«Traffic along Ofitserskaya Street from the side of Dzerzhinsky Street is one-way, the width of the roadway is 9 meters, the number of traffic lanes on this section is three, both sides of the roadway are equipped with sidewalks 1,5 m wide, the road surface is asphalt concrete. After crossing Neftyanikov Highway, traffic becomes two-way, with a roadway width of 18 meters and six lanes» [9].

Road markings are applied on Ofitserskaya Street, the condition of this marking is assessed as good. There is a traffic light at the intersection of Ofitserskaya Street and Neftyanikov Highway.

The intersection is shown in Pic. 6 on the map of the city of Krasnodar.

This intersection is controlled and equipped with a traffic light.

Also, during the work, a section of the street-and-road network of the Central District of the city of Krasnodar at the intersection of Ofitserskaya and Krasnaya Streets was considered.

«Traffic along Ofitserskaya Street is two-way, the width of the roadway along Ofitserskaya Street is 21 meters, the number of traffic lanes on this section is seven, on both sides of the roadway there are sidewalks 1,5 m wide, the road surface is asphalt concrete» [9].

Ofitserskaya Street has road markings, the condition of these markings is assessed as good.

The intersection is shown in Pic. 7 on the map of the city of Krasnodar.

This intersection is also controlled and equipped with a traffic light.

These intersections were chosen as the object of the study due to the high traffic intensity of both passenger and fixed-route vehicles. Its intensity is high because Ofitserskaya Street is

[1] Klinkovstein, G. I., Afanasyev, M. B. Road traffic management: Textbook [*Organizatsiya dorozhnogo dvizheniya: Uchebnik*]. 4th ed., rev. and enl. Moscow, Transport publ., 1997, 231 p., 231 p. ISBN 5-277-01959-6.

Pic. 6. The intersection of Ofitserskaya Street and Neftyanikov Highway on the map of Krasnodar [compiled by the authors].

Pic. 7. The intersection of Ofitserskaya Street and Krasnaya Street on the map of Krasnodar [compiled by the authors].

an arterial street connecting three districts of the city: Central, Prikubansky and Festivalny Districts.

With the existing traffic management scheme on Ofitserskaya Street in the segment from Kolkhoznaya Street to Neftyanikov Highway, unimpeded entry into the city from Rostovskoye Highway and Kolkhoznaya Street is difficult. The scheme is shown in Pic. 8.

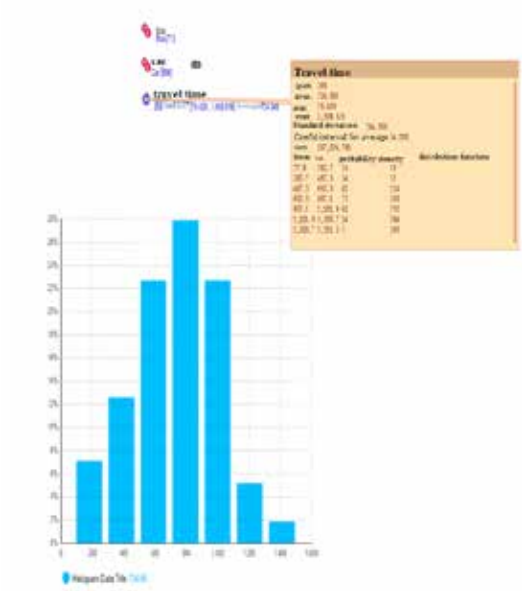
Under the current conditions and at the current traffic intensity, the average number of cars and the average travel time of this section per hour of traffic monitoring are estimated in the AnyLogic 8.7.5 program as 269 vehicles and 734 seconds.

During the survey of the intersection, various types of deficiencies were identified that interfere with normal traffic at the intersection of streets. These exact deficiencies are proposed by the authors to be eliminated by changing the existing traffic management scheme and creating a RPT dedicated lane.

After conducting field observations and assessing the viability of the existing traffic management scheme, the conclusion can be made about the need to design an improved traffic management scheme for the considered segment of the street-and-road network to increase its transit capacity towards the city centre. Besides, there is a need to reduce road traffic accidents' rate at this segment and improve road traffic safety for other road users.

First, it is necessary to improve the visibility of existing traffic signs, some of which are practically invisible due to green spaces [10].

Pic. 8. The existing scheme of traffic management on Ofitserskaya Street [compiled by the authors].



Pic. 9. Results recorded in AnyLogic after an hour long experiment [performed by the authors, screenshot of the program window during the experiment].

Changes were suggested to the traffic management on Ofitserskaya and Krasnaya streets, and on Neftyanikov Highway[2].

Thus, for the intersection of Ofitserskaya Street and Neftyanikov Highway, it was suggested to reconstruct the intersection so that it could be passed without traffic lights.

We will consider the proposed recommendations for each side of the intersection.

Ofitserskaya Street from the side of Krasnaya Street:

– To make the segment of the street from Krasnaya Street to Neftyanikov Highway one-way.

– To make the rightmost lane dedicated to RPT.

– To increase the number of traffic lanes from 4 to 5.

– To make two rightmost lanes (1 and 2) intended for right turns onto Neftyanikov Highway towards Luzana Street.

– To allow moving from the third lane in the middle straight towards Dzerzhinsky Street and left into the second lane of Neftyanikov Highway.

– To make two leftmost lanes (3 and 4) intended for left turns onto Neftyanikov Highway towards Krasnaya Street into the third and fourth lanes.

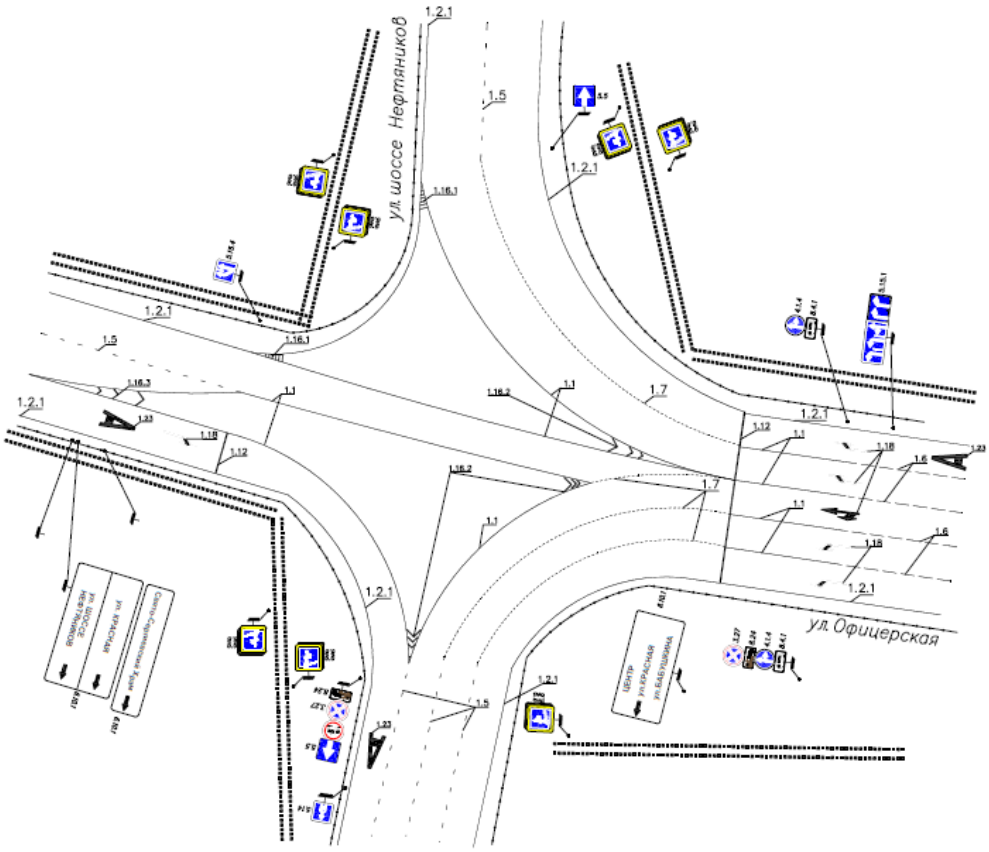
Thus, from this direction it will be possible to go in any of the three remaining directions.

Neftyanikov Highway towards Krasnaya Street:

– To make the rightmost lane (1) dedicated for buses, it will be possible to get to it from the dedicated lane from Ofitserskaya Street going from Dzerzhinsky Street.

– To make lanes 2, 3 and 4 only accessed from Ofitserskaya from Krasnaya Street.

[2] It is called in full «Street of Neftyanikov Highway», for simplification will be called further in the article «Neftyanikov Highway». – Transl. note.



Pic. 10. Proposed scheme of traffic management at the intersection of Ofitserskya Street and Nevtyanikov Highway [performed by the authors].

As a result, this segment remains practically unchanged and gets a special lane for public transport.

Ofitserskaya Street from the side of Dzerzhinsky Street:

– To make the segment of the street from Dzerzhinsky Street to Neftyanikov Highway two-way, one lane going towards Neftyanikov Highway, two lanes going in the opposite direction.

– To make the lane towards Neftyanikov Highway dedicated for buses, allowing only turn right along the lane into the first lane of Neftyanikov Highway towards Krasnaya Street.

– To make the first lane of Ofitserskaya Street towards Dzerzhinsky Street only be accessed from Krasnaya Street, from the third lane.

– To widen the first lane to two lanes, for this it will be necessary to widen the street, which is two-lane now at its beginning from Dzerzhinsky Street.

As a result of reconstruction, we will have a two-way street with one lane towards Neftyanikov Highway and two lanes towards Dzerzhinsky Street.

Neftyanikov Highway towards Luzana Street:

– To eliminate the possibility of exiting onto Neftyanikov Highway from Ofitserskaya Street from the side of Dzerzhinsky Street.

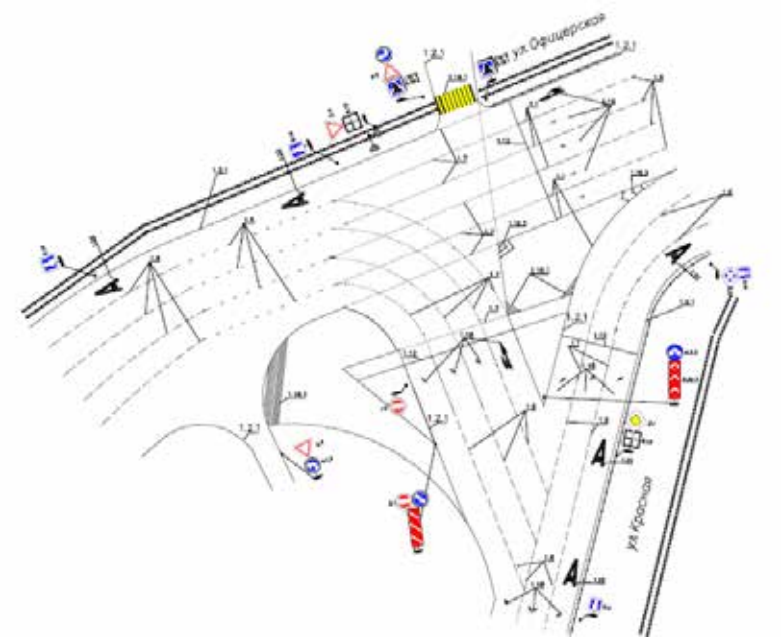
– To allow entry onto Neftyanikov Highway only from Ofitserskaya Street from the side of Krasnaya Street from the first and second lanes to the second and first lanes of Neftyanikov Highway, respectively.

– To move the public transport stop further from the intersection.

As a result, the direction segment will remain practically unchanged, and moving the stop will reduce congestion at the intersection.

The proposed traffic management scheme is shown in Pic. 10.

The final stage of changing the intersection of Ofitserskaya and Krasnaya streets is reconstruction of the intersection in such a way as to reduce the number of conflict points [11]. We will consider the proposed recommendations for each side of the intersection.



Pic. 11. Proposed scheme of traffic management at the intersection of Ofitserskaya Street and Krasnaya Street [performed by the authors].

Pic. 12. Proposed scheme of traffic management at Ofitserskaya Street [performed by the authors].

Ofitserskaya Street from the side of Rostovskoye Highway[3]:

• To make the segment of the street from Kommunarov Street to Krasnaya Street five-lane.

• To make it possible to turn from the rightmost lane (1) right into Orlovsky lane or go straight into the first lane of Ofitserskaya Street.

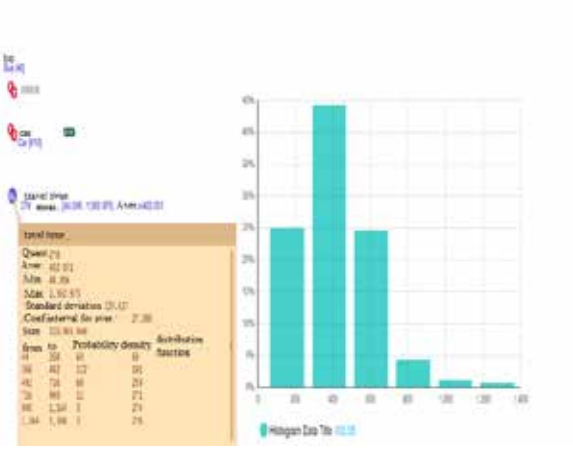
• To allow only straight traffic from lanes 2, 3, 4 and 5.

Thus, from this direction it will be possible to go either straight or into Orlovsky lane, as before, but the number of lanes from which it is possible to do this will be increased to five.

Krasnaya Street:

– To allow from the outer three lanes (1, 2, 3) to turn right unimpeded, without delay at the traffic light.

[3] Officially named «street of Rostovskoye Highway», same remark as for Neftyanikov highway. – *Transl. note.*



Pic. 13. Results recorded in AnyLogic during an hour long experiment [performed by the authors, screenshot of the program window during the experiment].

Table 1

Comparison of main indicators generated by AnyLogic [performed by the authors]

Travel time	Quantity	Average	Min	Max	Root-mean-squared deviation	Confidence interval for the average	Sum
Before	269	734.665	79.429	1508.19	284.563	34.006	197624.781
After	276	402.051	48.006	1362.975	229.637	27.092	110965.946

– To increase the number of lanes for straight movement and left turns by one.

– To allow straight movement and left turns into the second lane of Ofitserskaya Street towards Neftyanikov Highway from the fourth lane.

– To allow left turns into lanes 3, 4 and 5 from lanes 5, 6 and 7, respectively.

– To keep traffic light control only for straight movement and left turns.

As a result, the segment gets an additional lane for left turns and loses traffic light control for right turns towards Kommunarov Street.

Ofitserskaya Street towards Neftyanikov Highway:

- To make the segment of the street from Krasnaya Street to Neftyanikov Highway one-way.

• To increase the number of traffic lanes from 4 to 5.

• To allow access to all lanes from Ofitserskaya Street, from lane 1 to lane 1, from lane 2 to lane 2, respectively, etc., while from Krasnaya Street it will be possible to get into lanes 2, 3, 4 and 5 respectively and from Orlovsky Lane, only to lane 1.

After reconstruction, we will get a one-way street that can be accessed from any of the remaining three directions [12].

The proposed scheme of traffic management is shown in Pic. 11.

All the measures recommended for two intersections of Ofitserskaya Street will be effective if the following changes are additionally taken (Pic. 12):

– At the intersection of Ofitserskaya Street and Kommunarov Street, a left turn from Ofitserskaya Street (from the side of Rostovskoye Highway) to Kommunarov Street will be prohibited.

– A lane will be added to Kolkhoznaya Street for driving straight to Ofitserskaya Street.

– A lane will be added to Rostovskoye Highway for turning left to Ofitserskaya Street.

Under the proposed conditions and with the current traffic intensity, the average number of cars and the average travel time through this segment per hour of traffic monitoring are estimated in the AnyLogic 8.7.5 program as 3486 cars and 358 seconds.

The comparison of results is shown in Table 1.

If these recommendations are followed, it is possible to get rid of the traffic light control while turning onto Kommunarov Street from Ofitserskaya Street from the side of Rostovskoye Highway. Thus, on the segment of Ofitserskaya Street from Kolkhoznaya Street to Neftyanikov Highway there will be only three traffic lights, two for each direction of traffic.

BRIEF CONCLUSIONS

As a result of modelling the system, the conditions for movement of individual vehicles will worsen or remain unchanged, and the conditions for movement of urban passenger transport will improve. This may lead to redistribution of passenger traffic from individual vehicles to the vehicles of urban passenger transport, which will require recalculating transport flows in the further iterations [considering the change in the composition of the flow) [13].

Thus, based on the results of the experiment, it can be concluded that by applying this method in large cities, it is possible to achieve savings in the operating time of passenger transport [14]. This model is applicable not only to the transport system of Krasnodar, but also to the transport system of any city where there is an expressed need to reduce the congestion on the street-and-road network and the time it takes for people to move around the city [15].

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