

Транспортні потоки у великих містах мають неоднорідний характер виникнення та зміни. Основні параметри є часто чутливими до змін умов навколишнього середовища, а саме часу доби, сезону тощо. Величини, які характеризують транспортні потоки, мають стохастичний характер і тому їх спрогнозувати досить важко. Відповідно до цього, спостерігається нерівномірність таких показників як інтенсивність, щільність та швидкість руху у часі та просторі. З врахуванням цього, під час розроблення схем організації дорожнього руху виникає необхідність врахування додаткових чинників, які мають ймовірнісний характер. Такий підхід надає більш широкі можливості в процесі керування рухом і дозволяє використовувати відповідні шляхи до вибору методів організації дорожнього руху в тих чи інших випадках. Цей процес передбачає детальні дослідження показників дорожнього руху. Наведені підходи і методи щодо вивчення основних показників транспортних потоків. До них відносяться як натурні методи, так і імітаційне моделювання, яке передбачає врахування математичних і фізичних закономірностей руху транспортних потоків. Також це дозволяє прогнозувати ситуацію під час вибору тієї чи іншої схеми організації дорожнього руху з використанням комп'ютерної техніки. Проаналізовано результати досліджень, які проводились відповідно до описаних методик. Ці результати вказують на тісний зв'язок між відносним складом потоків за типами транспортних засобів та показниками черг та затримок в межах перехресть. Відповідно до результатів, отримано математичні залежності, які характеризують цей зв'язок. Встановлено, що вибір схеми організації дорожнього руху на перехрестях повинен проводитись із врахуванням складу транспортного потоку, оскільки кожен вид регулювання по-своєму ефективний для того чи іншого випадку

Ключові слова: склад транспортного потоку, транспортний потік, схема організації дорожнього руху, транспортна затримка

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1. Introduction

Development of modern cities, the population of which exceeds 500 thousand people, is uneven in nature, as different sectors and trends of this development have different dynamics. Such conditions promote an increase in motorization levels. In large and significant cities, this figure is much higher than the average indicator around the country. There arises the need to create new infrastructure elements, as well as to reconstruct morally and physically obsolete facilities.

Traffic flows in such cities are heterogeneous and dispersed in space and time, and this property often adversely affects the development of a settlement. This encourages architects and transport engineers to conduct research into the main indicators of traffic flows on a street and road network of urbanized spaces. The main planning solutions that determine the development of the city infrastructure should be based on the results of such studies.

Under limited geodetic and financial conditions, it is not always possible to improve the elements of a street and

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SELECTION OF A TRAFFIC MANAGEMENT SCHEME AT AN INTERSECTION TAKING INTO CONSIDERATION THE TRAFFIC FLOW COMPOSITION

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road network by creating new streets or junctions in different levels, which would greatly facilitate the solution of transport problems of the city. If there is no possibility to do this, it is necessary to improve the existing traffic patterns and reconstruct infrastructure facilities without any significant changes in their geometric parameters.

At present, there is a wide choice of methods for traffic management at intersections, including the introduction or elimination of traffic lights, as well as the arrangement of circular traffic. The appropriateness of their use is based on the rules and norms created, for the most part, in the last century. That is why the use of simulation tools provides an opportunity to study the effectiveness of each method of traffic control at intersections at changes in traffic flow indicators. Such solutions will solve the problem of delays when passing intersections. The choice of the ways of traffic management at intersections is one of the main activities that affect functioning not only of a particular node but also of the network in general. Based on this, the selected direction of research is relevant at present.

2. Literature review and problem statement

With the growing level of motorization, the problem of urban traffic is becoming increasingly serious. Traffic congestions not only negatively affect traffic safety and cause its delays, but also lead to significant air pollution, which has a negative impact on the environment. One of the main problems faced in large megacities is congestion. To solve this problem, researchers in paper [1] suggest adequate traffic control that can bring many benefits, including the reduction of pollutant emissions and the duration of passenger trips around the street and road network. Based on the results of this study, street sections are classified into three well-defined categories, which indicates the estimated distribution of vehicles during rush hours and makes it possible to optimize traffic for automated vehicles. However, there remains the problem of taking into consideration different types of vehicles on highway sections, as cars are the most autonomous vehicles in cities. That is why there is also a need for the research to determine the optimal schemes at an intersection, where transport delays will be minimal, which will have a positive influence on the reduction of pollutant emissions into the atmosphere.

The traffic composition is an important factor influencing the choice of planning decisions on traffic management at crossroads of highways and roads. It should be noted that such schemes should ensure maximum throughput of an intersection.

To meet the increasing demand for road transportation, a significant number of intersections were arranged and many major intersections, which play a positive role in reducing transport delays, were constructed. However, a large transport intersection is often complicated by the structure that has many ramps and routes of driving out, which easily leads to the situation when a driver cannot choose the traffic trajectory. In addition, there are obvious differences in motor vehicle speed while moving up and down the ramp. That is why traffic signs and information provision of drivers are of great importance to enhance traffic safety at a major intersection, especially for the traffic of trucks [2]. One of the options for improving traffic safety at complex intersections is the consideration of truck motion and their separation by creating separate turning lanes with a larger radius and smaller longitudinal slope.

A major intersection is a complex structure, which easily leads to drivers' misunderstanding of traffic directions. To ensure road safety, the research that focused on studying the technology of road signs installation at large intersections was carried out [3]. The results of visual recognition of these technical facilities indicate that it is necessary to improve the technology of placing the equipment for informing the drivers, in particular, to arrange signs with digital boards belonging to intelligent transport systems. However, apart from this, it is advisable to make specialized lanes for different types of vehicles on approaches to such transport nodes. This will make it possible to control traffic flows to reduce traffic congestions in cities and to ensure road safety taking into consideration such information boards.

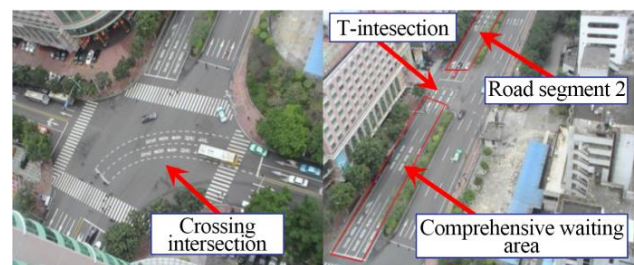
One of the major problems in choosing a traffic management scheme at intersections is uneven intensity and heterogeneity of the traffic composition [4, 5]. The authors note that the choice of traffic schemes in cities should be based on a comprehensive approach to the indicators of all traffic participants [4]. This approach according to the results of simulation of the intersection operation will give a quanti-

tative assessment for the choice of a traffic scheme with the least transport delays.

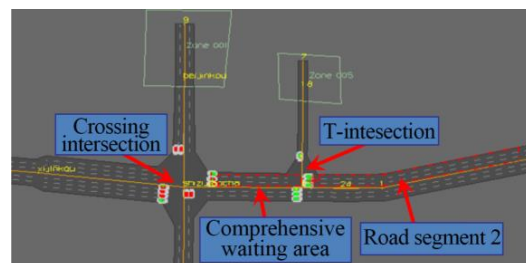
Paper [5] contains the study of the geometric parameters of the road network in Colombo (Sri Lanka), conducted to explain the schemes of traffic flows. The results of this study emphasize that drivers perceive space mainly depending on a geometrical distance (topological and angular distance), unlike a metric distance. That is why it is advisable to consider the type of vehicles during the analysis of the impact of planning parameters of streets and roads.

Research [6] deals with the main issues of the choice of the traffic management option at roundabouts with the use of the traffic criteria for the effective functioning of a street. The choice of the variant of traffic management is decisive for the traffic process because the time consumption for the passage of an intersection and passing safety depends on this. To select an optimal option for traffic management at a roundabout, it is proposed to study the following criteria: traffic speed and delay duration on approaches to an intersection. Under actual conditions, taking into consideration the uneven traffic flow, this task is time-consuming and requires considerable resources for the optimum choice of the traffic management type.

In analyzing the effectiveness of different options for traffic management in cities, it is necessary to take into consideration a great number of socio-economic criteria to make a full assessment. In studies [7] of the impact of a change in traffic management on urban intersections, it was proposed to arrange a comprehensive waiting area for turning vehicles. To enhance the management of the left-turning traffic flow, it is proposed to arrange a direct waiting area on an intersection itself. Traffic simulation was carried out using the software "PARAMICS" on the example of the city of Guangzhou for different traffic intensity. At the same time, the following indicators were evaluated: traffic delays, queue length, average traffic speed and the number of vehicles that passed an intersection. Implementation and simulation of a waiting area with vehicles are shown in Fig. 1 [7].



a



b

Fig. 1. Simulation of the comprehensive waiting area in the software PARAMICS [7]: a – existing state of traffic management at an intersection, b – the process of simulation of the traffic of motor vehicles

To implement the left turn in the “PARAMICS” platform, a street network, which makes it possible to simulate different traffic intensity, was created. The process of simulation of such a waiting area of vehicles makes it possible to estimate only the effectiveness of design solutions to improve traffic management at an intersection. Thus, it was determined that the waiting area operates effectively if the intensity does not exceed the street throughput on the approach to the intersection. Such waiting area will make it possible to reduce traffic delays at an intersection only partly, however, the existence of vehicles that are different in composition and dynamic characteristics will lead to the slowdown of the entire traffic flow. However, a detailed study of the composition of traffic flow at an intersection with the help of simulation will give an opportunity to assess all transport costs of different traffic schemes existing on it.

For better information support and understanding of drivers and in order to reduce traffic delays on the approaches to an intersection at the large traffic volume, it is necessary to develop a comprehensive strategy for managing such a waiting area.

In addition, the PTV Vissim software [8] is often used to assess traffic conditions at intersections. It is used to simulate traffic flows under conditions of saturated traffic for determining such indicators as the average length of delay, average queue length, speed of passing an intersection, etc. The authors of [9] analyzed traffic management at an X-intersection under the conditions of heavy traffic on the main road. Thus, traffic simulation in the PTV Vissim environment makes it possible to improve the parameters of the traffic management at an intersection and make an objective assessment of the current state of the flow indicators, but will not offer a distinct choice on the traffic scheme at an intersection. This is because the cause of significant traffic delays is often an uneven traffic flow and various dynamic characteristics of acceleration and slowdown of vehicles during the motion. Consideration of varying proportions of particular types of vehicles in a general flow during further research will make it possible to identify with what kind of traffic regulation at a crossroads the transport delays are minimal.

Congestions on the street-road network become more noticeable at an increase in the level of motorization, especially in large cities. This adversely affects the development of intelligent traffic systems in a city, in particular, an urban passenger transport system, which is focused on improving the efficiency of the traffic process, as it increases the duration of passengers' travel and leads to a decrease in the level of quality of passenger service on public transport and an increase in the costs of private transport motion [10]. At present, it is appropriate to carry out the research into traffic management taking into consideration public transport, in particular, large and low-floor buses, which form significant traffic delays on the approaches to an intersection.

The efficiency of a transport network depends on the performance characteristics of its various components. To improve the efficiency of traffic management schemes at intersections, it is necessary to create simulation models that will reflect their operation. This will make it possible to predict more accurately a change in traffic parameters on it than its analytical description [11]. This enables us to argue that in order to redesign the intersection scheme, it is necessary, in addition to analytical calculations, to create a simulation model for determining the maximum length

of the queue of vehicles in all its approaches. This makes it possible to simulate the intersection operation at various geometric parameters of roads on the duration of phases in the signaling cycle.

It is especially useful to assess various scenarios of traffic flow management in order to choose the best optimization measures to implement the relevant scheme of the traffic organization at an intersection.

Paper [12] contains the findings of the research into the mixed traffic flow at a signalized intersection, which identify the main danger for traffic occurring on pedestrian crossings during the interaction of a pedestrian and a transport flow that turns right. However, the problem of the impact of other turning maneuvers on the safety of pedestrians remained unresolved. This problem can be solved by re-planning or separation of traffic and pedestrian flows in time.

According to the foregoing, it was found that various kinds of the simulation are often used today to detect the shortcomings in traffic management schemes. However, it is also advisable to use these methods to select and justify the planning characteristics of intersections that take into consideration the vehicle flow parameters.

3. The aim and objectives of the study

The aim of this study is to identify the regularities of a change in the delay duration in a traffic flow for various traffic management schemes. In the future, this will make it possible to approach in a comprehensive way the choice of traffic management schemes at intersections of city streets taking into consideration the intensity and traffic composition, which in turn will contribute to a decrease in the duration of traffic delays at them.

To accomplish the aim, the following tasks have been set:

- to carry out the field research into primary indicators of traffic flows at intersections;
- to carry out the simulation of the operation of intersections in the PTV Vissim programming environment for various traffic management schemes;
- to determine dependences of a change in the average duration of vehicle delays on the approaches to an intersection for various traffic management schemes and traffic composition;
- to develop practical recommendations for taking into consideration the traffic composition when designing new and reconstructing existing traffic management schemes.

4. Methods of field studies of primary indicators of transport flows and simulation of crossroads operation using the software PTV Vissim programming environment

4.1. Field studies of intensity, speed, and composition of traffic flows

Registration and processing the data about specific traffic conditions, which takes place during the assigned duration of the time, is called field studies. This group of methods is the most common and is distinguished by great diversity. This approach is the only way to obtain reliable information about the state of roads, it enables obtaining accurate characteristics of existing traffic and pedestrian flows [13].

The field studies of traffic can be carried out using the following methods [2, 14]:

- passive (traffic modes that have just been formed, without researcher's interference);
- active (are not only limited to registration the existing situation but also ensure the check of parameters at a partial change of traffic conditions).

It is necessary to gather a significant amount of data about traffic conditions and traffic flow to study the motion of vehicles and to make a proper analysis of obtained results. At the same time, the effectiveness of field studies can significantly increase using the experiment planning methods [15].

In the classical sense, it goes about the operative traffic recording, which is carried out by a group of researchers. This process involves recording the main indicators of a traffic flow, such as traffic intensity for directions, the proportion of each type of vehicles in a flow, traffic speed, as well as the magnitude of delays and queues before intersections. It should be noted that the number of people involved, and the research complexity, are different for each separate case and depends on the road situation and geometric features of an intersection.

The obtained results are processed with the help of software, which has the functions of statistical and graphical data analysis, as visualization makes it possible to focus on the important points when evaluating the existing state of traffic management. The results, obtained by the method of field studies, are used both for the estimation of indicators of the effectiveness of intersections' operation and their safety and as input data in the construction of traffic simulation models.

4.2. Procedure of the construction of a simulation model of traffic flow in the PTV Vissim programming environment

Simulation is one of the well-known methods for the study of traffic flow and its characteristics. Its merit is that it is possible to explore how the simulation model of the intersection operation changes over time or under the influence of various impact factors.

There is a wide range of tasks to be solved with the help of the PTV Vissim software [8]:

- construction of a traffic network of any complexity taking into consideration individual and speed features of roads and streets;
- simulation of signalized and unsignalized intersections;
- choice of the optimal traffic management scheme for an intersection;
- estimation of the throughput for different traffic management schemes;
- simulation and optimization of operation of traffic light devices;
- prediction of traffic jams;
- simulation and analysis of pedestrian motion;
- a wide range of analyses for vehicles, pedestrians, traffic light devices, public transport routes, etc.

The road traffic parameters at an intersection change over time and with a significant amount of randomness and concurrent interactions. The most difficult and important process in the simulation of traffic flow is the calibration of a simulation model to reproduce the actual operation of an intersection with the desired accuracy. In addition, modeling

makes it possible to determine the influence of traffic flow on the effectiveness of the operation of a traffic management scheme at an intersection.

Specifically, the software PTV Vissim developed by PTV Group (Germany), for example, version 8, can display and visualize the complicated motion of traffic flow in a graphical way. It is also possible to assess the physical impact on the traffic parameters of alternative schemes of a change in traffic management schemes at intersections.

5. Analysis of indicators of traffic flows and results of their simulation at intersections with various traffic management schemes

5.1. Results of field studies of the motion of traffic flows

To simulate the motion of traffic flows in software environment PTV Vissim, the section of a street and road network, specifically, signalized X-shaped channeled intersection, was selected. The streets that form it have the following parameters:

- street A – three traffic lanes in each direction with the width of 3.75 m., type of cover – asphalt concrete;
- street B – two traffic lanes in each direction with a width of 3.5 m., type of cover – asphalt concrete.

The schematic representation of the allowed traffic directions at an intersection is shown in Fig. 2.

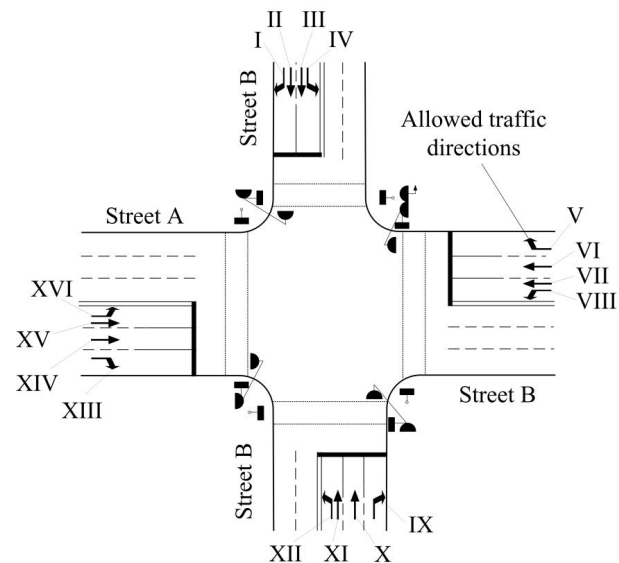


Fig. 2. Scheme of the crossroads and allowed directions of traffic flows and their numbering

Traffic regulation at an intersection is performed at three phases:

- phase 1 – flows IX, X, XI, XII;
- phase 2 – flows I, II, III, IV, V, XIII, IX;
- phase 3 – flows VI, VII, VIII, XIV, XV, XVI.

The continuous motion of traffic flows V, IX, XIII is allowed on condition that there is no interference.

Based on the analysis of the results of field studies at the specified intersection of streets, the data on the reduced traffic flows intensity were found. According to this, the diagram (Fig. 3) and the chart of traffic composition (Fig. 4) were constructed.

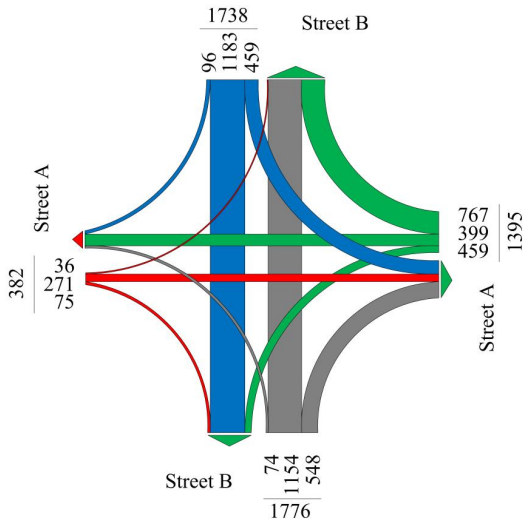


Fig. 3. Diagram of the intensity of traffic flows at the studied intersection of streets

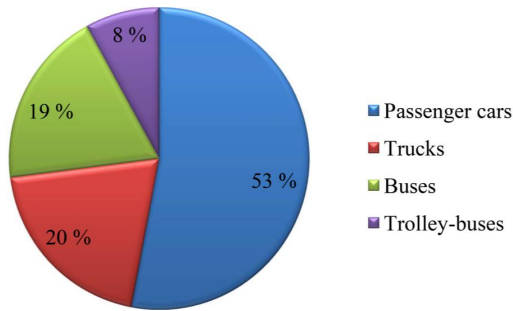


Fig. 4. Chart of the traffic composition at the studied crossroads

5. 2. Simulation of intersection operation for various traffic management schemes

Using the PTV Vissim programming environment, we downloaded the fragment of the satellite map of the studied intersection and made appropriate calibration. The streets that form a model of the studied intersection, indicating the appropriate width of traffic lanes, were created. The allowed traffic directions at the intersection were marked by means of connecting segments. The value of traffic intensity on each approach with the appropriate distribution of the traffic composition was introduced according to the results of field studies. The speed limit on the intersection segments was set and appropriate traffic priorities for letting the vehicles that complete a maneuver or move along “the main road” (street A) were given. The points of measuring the duration of vehicle delays were set.

When modeling the traffic in the software environment, three different models with the following traffic management schemes were created:

- signalized intersection (Fig. 5, a);
- unsignalized intersection (Fig. 5, b);
- roundabout (Fig. 5, c).

The model of a signalized intersection is equipped with traffic lights facilities and assigned a traffic light cycle of the duration of allowing and prohibiting signals according to the existing traffic management state. During the construction of the models, the share of passenger cars and trucks and public transport was changed to determine the average length of traffic flows delays on the approaches.

To compare the changes in the average traffic flow delay, the modes of vehicle motion, in which the percent ratio of the traffic flow composition was artificially altered and simulation of their motion was carried out. First of all, the share of cars in traffic flow was changed. The found ratio is given in Table 1.

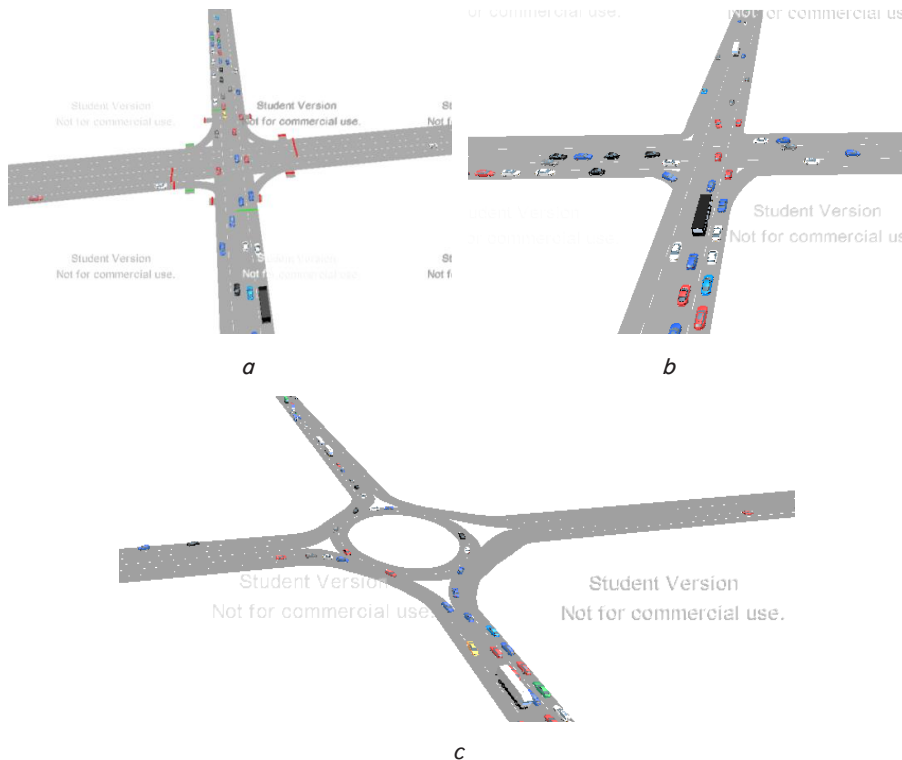


Fig. 5. Models of the studied intersection with different traffic management schemes: a – signalized; b – unsignalized; c – roundabout

Table 1
Percent ratio of traffic composition at a change in the share of passenger cars

Share of passenger cars, %	Share of trucks, %	Share of public transport, %
50	20	30
55	18	27
60	16	24
65	14	21
70	12	18
75	10	15
80	8	12
85	6	9
90	4	6
95	2	3

The dependence of average delay on various models of intersections with a change in the share of passenger cars is shown in Fig. 6.

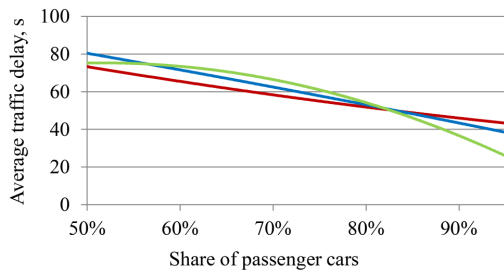


Fig. 6. Dependence of duration of average traffic flow delay with a changing share of passenger cars on the studied intersection of streets at various traffic management schemes: — signalized intersection; — non-signalized intersection; — roundabout

In another case of the experiment, the share of trucks in a flow was changed. The applied percent ratio, in this case, is shown in Table 2.

Table 2

Percent ratio of the traffic flow composition at a change in the share of trucks

Share of trucks, %	Share of passenger cars, %	Share of public transport, %
2	64	34
4	62	34
6	61	33
8	60	32
10	59	31
12	57	31
14	56	30
16	55	29
18	53	29
20	52	28

In this case, the change in the duration of the average delay is shown in Fig. 7.

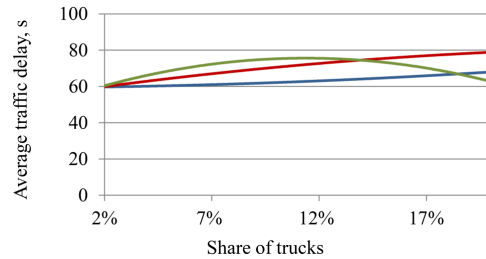


Fig. 7. Dependence of duration of average delay in a traffic flow with a changing share of trucks at the studied intersection of streets for various traffic management schemes: — signalized intersection; — unsignalized intersection; — roundabout

In addition, the share of public transport in the flow was changed. The percent ratio used in this case is given in Table 3.

Table 3

Percent ratio of traffic flow at the change of the share of public transport

Share of public transport, %	Share of trucks, %	Share of passenger cars, %
3	25	72
6	24	70
9	24	67
12	23	65
15	22	63
18	21	61
21	21	58
24	20	56
27	19	54
30	18	52

Dependence of a change in average delay duration on the share of public transport in a flow for various traffic management schemes is shown in Fig. 8.

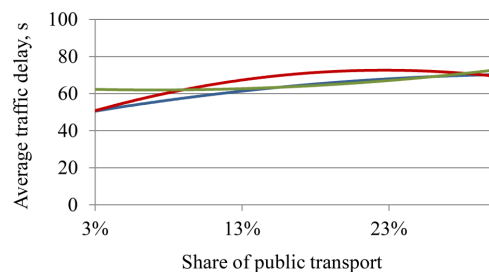


Fig. 8. Dependence of the duration of average delay in traffic flow with a changing share of public transport at the studied intersection of streets for various traffic management schemes: — signalized intersection; — unsignalized intersection; — roundabout

5.3. Regularities in a change in the duration of vehicles' delays on the approaches to an intersection for various traffic management schemes

By processing the obtained values using the Microsoft Excel 2016 programming environment, the appropriate mathematical dependences were established (Table 4).

Table 4
Mathematical dependences of a change in the average duration of traffic delays on approaches to an intersection for various traffic management schemes

Type of vehicle, the share of which changes	Traffic management scheme on a simulated intersection		
	Signalized intersection	Unsignalized intersection	Roundabout
Cars	$t_d = 32,888\alpha^2 - 114,37\alpha + 122,26$	$t_d = -14,387\alpha^2 - 72,512\alpha + 120,27$	$t_d = -263,47\alpha^2 + 272,34\alpha + 4,9139$
Trucks	$t_d = 153,78\alpha^2 - 12,081\alpha + 59,393$	$t_d = -281,46\alpha^2 + 167,15\alpha + 56,663$	$t_d = -1732,8\alpha^2 + 394,32\alpha + 53,152$
Public transport	$t_d = -205,78\alpha^2 + 140,61\alpha + 46,541$	$t_d = -563,96\alpha^2 + 255,91\alpha + 43,581$	$t_d = 201,25\alpha^2 - 28,561\alpha + 62,983$

After conducting the experimental simulation of the traffic flow at an intersection in the PTV Vissim programming environment, it was found that the longest duration of the average delay is observed in the model of an unsignalized intersection (82 s), and the shortest – 29 s at an unsignalized intersection. However, it should be noted that the delays of a single vehicle from 27 to 115 min were observed on some approaches to the intersection during the simulation.

6. Discussion of results of studying the influence of parameters of a traffic flow on the choice of traffic management scheme at an intersection

The conducted studies of the parameters of traffic flows at the city intersection allowed creating the appropriate models of such sites with various traffic management schemes. Based on this, a graphical representation of the average duration of vehicle delay was created. Analysis of the data shown in Fig. 6–8 revealed that a change in the share of a certain type of vehicles in the flow affects the studied indicator on the approaches to simulated intersections. It should be noted that the obtained research results can be used at intersections with similar planning parameters that are located in large cities.

It is found that if there are more than 80 % of passenger cars in a traffic flow, it is advisable to use the traffic management scheme, which is provided by roundabouts. This is because passenger cars have good dynamic indicators and overall dimensions are smaller compared to trucks and public transport vehicles. According to this, a driver can increase speed in short intervals, quickly change a traffic lane in the interlocking areas of a roundabout, etc. It was also established that in the presence of a large proportion of passenger cars in a flow, the average duration of delays on approaches to simulated intersections is in the range of 20 and 50 s.

If the share of trucks in a traffic flow is between 2 % and 18 %, it is recommended to design the traffic light system at an intersection. The results of the simulation suggest that

the average delay duration under such conditions ranges from 58 to 81 s, in this case, this value increases with an increasing share of trucks. This is because, considering the dynamic indicators of trucks and their overall dimensions, it is more difficult for drivers to pass it if it is an unsignalized intersection or roundabout. It should be noted that at an unsignalized intersection, the average traffic delay duration is largely affected by the motion of trucks that gave traffic priority to vehicles on the main direction of an intersection.

As for the simulation of the operation of intersections with various traffic management schemes and a changing share of public transport in the flow, the average delay duration ranged between 49 and 76 s. However, it was impossible to identify a certain traffic management scheme at an intersection, which would ensure the proper throughput of traffic flows at various shares of public transport. This is because the obtained values were very close and we did not find any distinct advantage of a certain traffic management scheme at an intersection. That is why in the presence of a significant share of this type of transport in a flow, it is advisable to dedicate the public transport lane, which can reduce the duration of delay of buses, trolleybuses, trams, etc. and reduce their mutual influence on other types of vehicles in a flow.

In accordance with the above, it can be argued that when designing new and reconstructing the existing sections of the street and road network, in particular intersections, it is necessary to consider the existing or future traffic intensity and the traffic composition. Owing to the simulation whose results indicate that these uneven parameters to a large extent affect the average traffic delay on all approaches to an intersection, the optimal traffic management scheme at an intersection, which best satisfies the needs of heterogeneous traffic flows, was determined. In addition, it should be noted that the proposed approach makes it possible to reduce traffic delays, in particular, in cases where it is impossible to arrange multi-level intersections. At the same time, in order to avoid possible engineering errors on the choice of the traffic management scheme, it is necessary to use the appropriate software to simulate the designed conditions and the way traffic participants use them.

According to the research results, we identified the relationship between the traffic flow composition, traffic management schemes at intersections and the values of the average duration of traffic delays. Based on this, it is planned to continue extending the subject matter of the research, taking into consideration the parameters of pedestrian and bicycle flows.

7. Conclusions

1. The field research into the parameters of traffic flows with the use of photo-video equipment on the section of a street and road network of a big city was carried out. The intersection is X-shaped, equipped with a traffic light regulation system. Each approach to the intersection is multi-lane without significant slopes. Using the documentary method, the analysis of the established data was performed; the flow composition and the share of vehicles moving in different allowed directions were determined. It was found that currently it is dominated by cars (53 %).

2. Based on the established parameters of traffic flows, the model was created in the PTV Vissim programming environment for the existing (signalized) traffic management scheme. Based on the created model, two other variants of traffic management schemes at an intersection, in particular, roundabout and unsignalized intersection, were designed. The creation of such simulation models involved the actual display of a traffic network, taking into consideration the geometric and engineering parameters of roads in the various traffic management schemes. During the simulation of traffic at intersections, it was found that each of these traffic schemes has its own characteristics and to a different extent affects the duration of delay of vehicles in a flow, which ranged from 27 to 115 s. Such estimation of intersection operation makes it possible to determine the main “bottle-necks” at intersections at a change in the main transport flow indicators.

3. According to the simulation results, the values of the average length of delays of vehicles in a flow for various traf-

fic management schemes at an intersection were established. Based of this, it was found that under such traffic conditions, the duration of vehicles delay varies, in particular, at a large number of cars on the roundabout, they can reach the value of 29 s, while at a large share of trucks at an unsignalized intersection they can reach the value of 82 s. On this basis, the dependences of a change in the average duration of traffic delays on the approaches to the intersection for the various traffic management schemes and the traffic flow composition were identified.

4. It was established that depending on the traffic composition, it is advisable to use different variants of design solutions, in particular, to change the traffic management at intersections. It should be noted that the general city development plans take into consideration a change in planning parameters, in particular, the arrangement of fly-over intersections. However, given the cost of these works, such solutions are often impossible to implement considering possible funding.

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