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ANALYSIS OF TRAFFIC ORGANIZATION AND OPTIMIZATION AT THE INTERSECTION OF BALZAC AND KASHTANOVA STREETS IN KIEV

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The rapid development of all types of transport and transport communications and the increase in the number of vehicles in Ukraine leads to traffic organization problems and as a result to a high level of traffic accidents. This paper focuses on the existing problems of Balzac and Kashtanova streets in Kiev. In order to improve traffic organization on the existing area the following steps were made: making a 3D model of the intersection, calculations of an intermediate signal and the cycle time determination, defining phase calculations of particular direction, and determination of the green signal time. Necessary suggestions to regulate traffic organization at the intersection include entering two-phase traffic lights, setting pedestrian traffic lights and the sign «parking is prohibited», using priority signs. Using these strategies, it will be possible to solve the traffic organization problems and to increase the traffic safety in the area.

Keywords: traffic organization, traffic safety, 3D modulation, intersection.

Introduction. The modern era is characterized by a growing level of industrial development of natural resources and increase of manufactured products, increase of consumption of products of industrial and agricultural production, intensive industrial and civil construction, a sharp increase in mobility of the population, the desire to reduce the time of goods delivery and especially passengers. This, in turn, causes a sharp increase in demand for transportation and, as a consequence, the rapid development of all types of transport and transport communications and the rapid increase in the number of vehicles. High rate of motorization leads to increase traffic accidents.

As a result of road traffic accidents on the roads killing thousands of people, hundreds of thousands of people are injured with long or short-term health disorders.

In our country much has been done to solve the problem of traffic organization. The design and reliability of domestic cars have been improved, the roads, underground and overhead pedestrian crossings have been built and reconstructed in different levels, modern technical means of traffic organization improving the maintenance of streets and roads have been applied.

The role of road conditions, ensuring safety and the value of improvement yet to a sufficient degree underestimated. They can be fully revealed only through extensive research on the analyses of traffic accidents and study of the modes of movement of vehicles in different road conditions.

As a rule, the circumstances of road accidents are extremely diverse. However, the analysis of these circumstances allowed us to identify some General characteristics that gave the chance to develop a classification of road traffic accidents.

There has already been done previous research on analysis of traffic organization in Ukraine. Tarasuk and Karpenko (2014) using drawings and PTV VISSIM software analyzed the reconstruction of the road section on the Paton bridge. Fediushin (2014) analyzed car movement and traffic jams and identified problem areas in the city of Kiev. Ukrainian transport university (2015) analyzed route planning movement, assessed the download of crossroads, defined difficulties and dangers of the crossroads organization and organization of movement of buses.

Goals of the present work:
1) to find the problem area on the road;
2) to analyze traffic area;

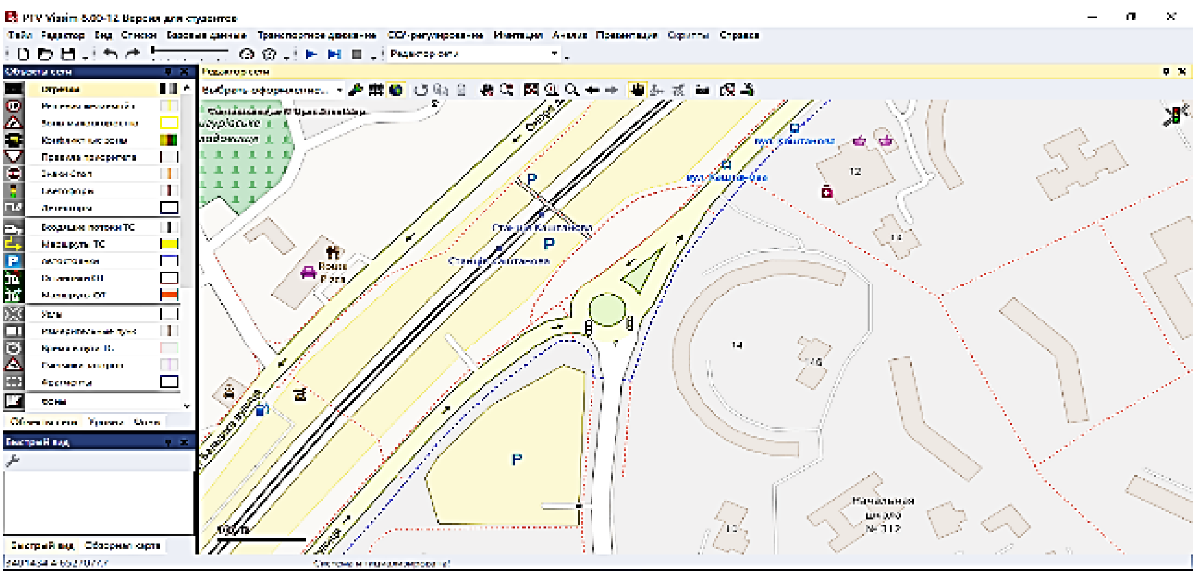

Fig. 1. Troyeshchyna area

3) to improve the organization of road traffic at this area.

The characteristics of an existing area. Troyeshchyna is the intersection of Balzac and Kashtanova streets (shown as Fig. 1). There is the fairly complex interchange with the flowerbed, in front of witch the road narrows from three rows to two. Right after the turn onto the street Kashtanova in front of the driver there is a «surprise» – an unregulated pedestrian crossing, which is still not lit. The danger of tragic accidents involving a pedestrian and a car is very high.

Fig. 2. 3D «PTV Vissim 9» Model of the intersection of Balzac and Kashtanova streets

Survey of streets and roads is the first step in the development of measures to improve traffic safety and transport-operational qualities of streets. In this process all the data necessary for the development of projects of reconstruction of streets and traffic management should be obtained. It is useful to demonstrate the transport flow model on the road, which will show all traffic problems on that particular road area.

The following drawing helps to see clearly how the crossroad looks like (Fig. 2).

The intersection of Balzac and Kashtanova streets can be characterized with traffic jams, queue delays and high occupation rate, especially in the period of time from 4pm to 7pm. According to these data there was conducted a research using «PTV Vissim 9» software. The calculations and measurements are presented in the Chart below (Fig. 3).

Methods of improvement of traffic organization at the intersection of Balzac and Kashtanova streets

The level of motorization in the capital is much higher than the average in Ukraine, which is 148 cars per 1000 people. In Kiev, this figure is kept at the level of 213 cars per 1000 inhabitants.

In the course of a large-scale sociological survey, 1800 households were recorded in the surveyed households. The number of people in these households was 84,600.

The average number of people in one household is 2.9 people. So, an average of 0.213 vehicles per person is obtained.

It is indicative that the level of automobile ownership in Hong Kong is 59 cars per 1000 inhabitants, Istanbul – 139, New York – 209, Moscow – 297, Berlin – 317, London – 345, São Paulo – 368 cars per 1000 inhabitants.

Previously it was believed that the level of motorization in Kiev is about 345 cars per 1000 inhabitants. This number was obtained, apparently, based on the ratio of the number of officially registered cars to officially registered citizens.

1. Calculation of an intermediate signal.

The task of this calculation is to find the duration of the intermediate interval (transitional interval), which would ensure complete and safe release of the intersection after the end of one of the main measures. With this vehicle, suitable for crossing from any direction to a green signal with a speed of free movement when the traffic light signal changes from green to yellow, it must stop at the stop lines before the end of the intermediate step or be released for the same with time of the intersection.

$$T_{ii} = \tau_1 + \tau_2 - \tau_3 + 2 \quad (1)$$

where τ_1 – travel time (without speed reduction) of

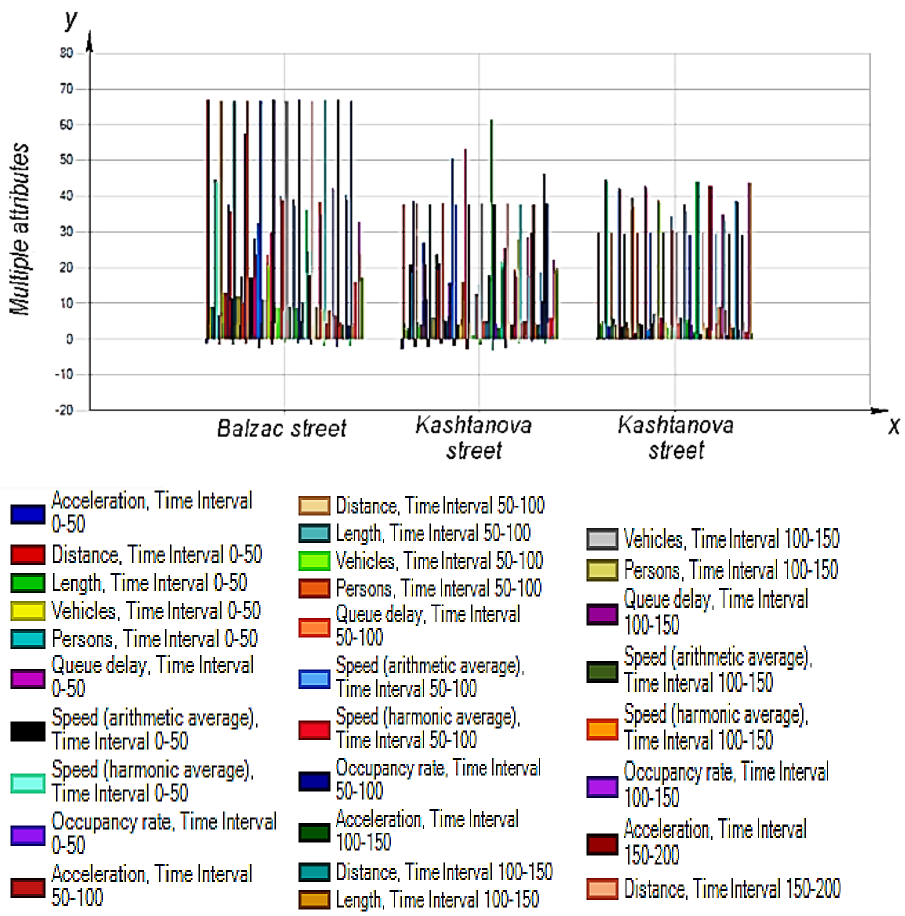

Fig. 3. Data collection Measurements of the intersection of Balzac and Kashtanova streets

the distance to the stop line equal to the stopping distance, sec.;

τ_2 – travel time of the distance from the stop line to the farthest conflict point, taking into account the length of the vehicle, sec.;

τ_3 – the time from the moment when the green signal is turned on in the next phase until the vehicle or pedestrians have started moving to the conflict point, which began to move to this signal, sec.;

I phase:

$V_a = 45$ km/h.

$l_1 = 80+3+2 = 85$ м.

$l_1 + l_a = 91$ м.

$\tau_1 = 3,2$ с.; $\tau_2 = 4,5$ с.; $\tau_3 = 3,9$ с.

$$T_{ii1} = 3,2 + 4,5 - 3,9 + 2 = 5,8 \text{ с.}$$

We will take $T_{ii1} = 6$ s, rounding to the nearest whole number.

II phase:

$l_1 = 40+3+2 = 45$ м.

$l_1 + l_a = 51$ м.

$\tau_1 = 3,2$ с.; $\tau_2 = 4,0$ с.; $\tau_3 = 3,9$ с.

$$T_{ii2} = 3,2 + 4,0 - 3,9 + 2 = 5,3 \text{ с.}$$

We will take $T_{ii2} = 5$ s, rounding to the nearest whole number.

III phase:

$l_1 = 70+3+2 = 75$ м.

$l_1 + l_a = 81$ м.

$\tau_1 = 3,8$ с.; $\tau_2 = 5,4$ с.; $\tau_3 = 3,9$ с.

$$T_{ii3} = 3,8 + 5,4 - 3,9 + 2 = 7,3 \text{ с.}$$

We will take $T_{ii3} = 7$ s, rounding to the nearest whole number.

In order to calculate the accurate flow density of the road section the following formula will be used:

$$M_H = 525 \cdot W \quad (2)$$

This formula calculates saturation flux for the case of traffic in the forward direction along the road without longitudinal slopes.

where: M_H – the saturation flux, given unit/hour;

W – width of the carriageway in the given direction of traffic, m.

I Phase:

For one band:

$$M_{H1} = 525 \text{ x } 2,75 = 1443 \ u/h$$

For three bands:

$$M_{H1} = 525 \text{ x } 8,25 = 4331 \ u/h$$

II phase:

For one band:

$$M_{H2} = 525 \text{ x } 3,50 = 1837 \ u/h$$

For two bands:

$$M_{H2} = 525 \text{ x } 7 = 3675 \ u/h$$

III Phase:

For one band:

$$M_{H3} = 525 \text{ x } 3.50 = 1837 \ u/h$$

For two bands:

$$M_{H3} = 525 \text{ x } 7 = 3675 \ u/h$$

2. Phase coefficients.

The value of the phase coefficient characterizes the degree of density of particular direction.

$$y_i = \frac{N_i}{M_{Hi}}, \quad (3)$$

where: N_i – the intensity of movement in a given direction, units/sec.;

M_{Hi} – is the saturation flux in a given direction, u/s.

I Phase:

$$y_1 = \frac{840}{4331} = 0.20$$

II Phase:

$$y_2 = \frac{660}{3675} = 0,180$$

III Phase:

$$y_3 = \frac{660}{3675} = 0,180$$

3. The cycle time determination.

The task of this calculation is to find a duration of the control cycle under given driving conditions, which would provide the minimum value of the average delay of the car at the intersection.

$$T_{C_O} = \frac{1,5 \cdot L+5}{1 - \Sigma y}, \quad (4)$$

where: L – total lost time of the intersection, sec.;

Σy – total phase cross-ratio

$$L = \Sigma(T_{ii} - 1). \quad (5)$$

$$L = (6–1) + (5–1) + (7–1) = 15 \text{ с.}$$

$$T_{C_O} = \frac{1,5 \cdot 17 + 5}{1 - (0,200 + 0,180 + 0,180)} = 60 \text{ с.}$$

4. The green signal time determining.

If the cycle length T_C is found, then it is possible to determine the durations of the phases.

$$t_{3\ i} = \frac{(T_C - L) \cdot y_i}{\Sigma y}, \quad (6)$$

T_C – the duration of the control cycle, s.;

L – the total lost time of the intersection, sec.;

y_i – the phase coefficient;

Σy – the total phase coefficient of the intersection.

$$t_{3\ 1} = \frac{(39,2–12) \cdot 0,154}{0,414} = 10 \text{ с;}$$

$$t_{3\ 2} = \frac{(39,2–12) \cdot 0,146}{0,414} = 9 \text{ с;}$$

$$t_{3\ 3} = \frac{(39,2–12) \cdot 0,114}{0,414} = 8 \text{ с;}$$

5. The scheme of intersection organization with technical means of regulation (Fig. 4, 5).

6. The arrangement of technical means of regulation at the crossroads of Balzac and Kashtanova streets.

The traffic at the crossroads of Balzac – Kashtanova streets is carried out by means of a two-phase traffic light regulation with pedestrian pass. In the absence of strict regulation, traffic at the intersection is carried out using priority signs: «main road»; «Give way». Road marking: «separation of traffic flows moving in opposite directions»; «separation of traffic flows moving in the same direction»; «stop line»; «Pedestrian crossing».

7. The proposed scheme of arrangement of technical means of regulation.

At the crossroads of Balzac-Kashtanova streets it is proposed to enter two-phase traffic lights and to set pedestrian traffic lights. In the absence of strict regulation, traffic will be carried out using priority signs: the main road is Balzac Street, which is confirmed by the sign «main road»; a secondary street is Kashtanova, where sign «give way» is set. At the intersection in the forward and reverse directions along the main road, sign «parking is prohibited» is required. The recommended speed is a speed of 50 km/h.

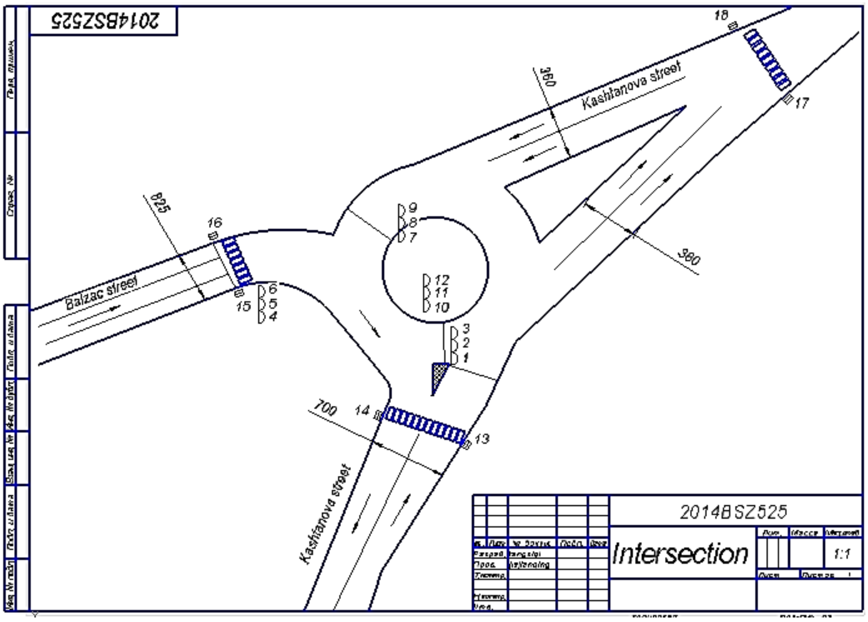

Fig. 4. 2D Scheme of technical organization of regulation means of the given intersection

Traffic light numbers	Phase cycle (Tc=40 s)				Duration t_g	t_y	t_r	t_{ry}
4,5,6,10,11,12	green	yellow	red	r/y	30	5	20	5
1,2,3,7,8,9	red	r/y	green	yellow	20	5	30	5
15,16	red		green		23	-	37	-

Fig. 5. The schedule of traffic light objects

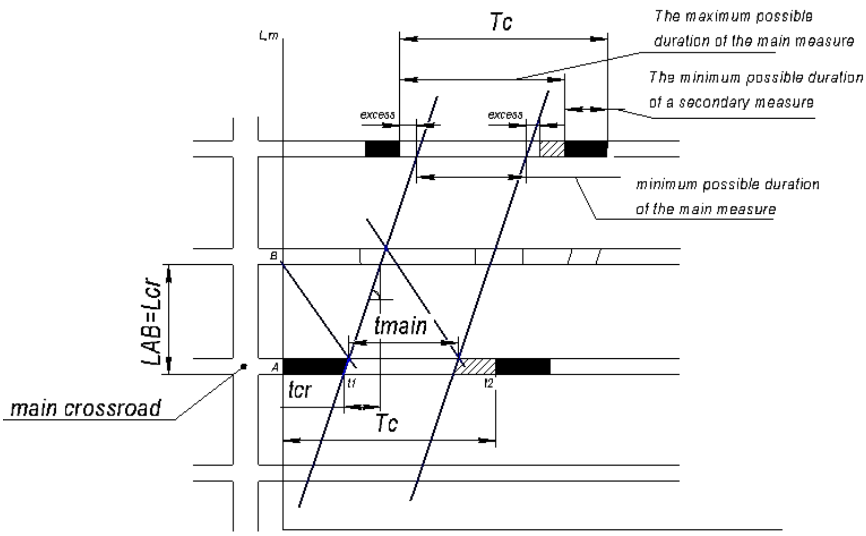

Fig. 6. Building a coordinated regulatory chart

Coordinated regulation

1. General provisions

Coordinated regulation is one of the forms of adaptive program control, usually without feedback, and is cast from similar rigid regulation at an isolated intersection in that it is intended to be used simultaneously at several intersections. The goal of coordinated regulation is to ensure non-stop traffic flow along the street. Coordination of neighboring intersections ensures a reduction in the number of non-stopping stops and braking in the flow, as well as the level of transport delays.

Numerous studies recommend that the signals be coordinated at distances between adjacent intersections not exceeding 800 m. When distances between intersections are greater than 800 m, it is recommended to install intermediate traffic lights (for example, on the regulated pedestrian crossings), thereby artificially reforming groups of cars.

The essence of coordinated regulation can be explained with the aid of Figure 6 a car leaving at time t1 intersection A and moving at a constant speed V passes the street without stopping in the direction B-3. Similarly, the car leaving the intersection at time t2 moves. The boundaries t1 and t2 form the width of the «green» tape, i.e. time lanes, moving «inside» which cars will drive through the street without interruption. The difference t2 – t1 also represents the «length» of a group of cars for which non-stop traffic is provided. The conditions for the stability of this regulating regime are:

1. the same cycle of regulation at all crossroads of the street;
2. the constant magnitude of the phase shifts at adjacent intersections.

By the phase shift we mean the time interval between the beginnings of the main measure («green») at the previous and subsequent intersections. Obviously, the magnitude of the phase shift is always less than or equal to the control cycle. The combination of phase shifts, phase durations and a regulatory cycle for all street crossings that are part of a coordinated regulatory system form a program or coordination plan (Fig. 6).

The task of engineering calculation is the preparation of coordination programs for given traffic conditions.

There are several types of coordinated control systems by the way the coordination program is organized.

The first of these is called a simultaneous or synchronous system. In such a system, all traffic signals at intersections at any time have the same indication, and the phase shifts are zero. If the distance between two intersections is l (the distance in meters between the stop lines or the intersection centers), then in order to move non-stop, the car leaving the first intersection must have a speed of movement:

$$V = \frac{\ell}{T_c}, \quad (7)$$

where: V – speed, m/s;
T_c – the cycle time, s.

To ensure the operability of such a system, it is necessary that the distances between the crossroads be approximately equal, which is achievable in practice only in rare cases. As a rule, this method of regulation is used at very high traffic intensities, close to the capacity of the highway.

Conclusions. In the present paper there was analyzed the particular area of Balzac and Kashtanova streets in Kiev and existing problems of traffic flow and density were solved. Most complex areas of the intersection were taken into account and calculated. Using PTV Vissim 9 program 3D model of the intersection which helped to accumulate data collection results was made. Calculations of an intermediate signal helped to define safe release of the intersection after the end of one of the main measures. The cycle time determination was used to define and find a duration of the control cycle under given driving conditions. Phase coefficient measurements facilitated to calculate the degree of density of particular direction. Determination of the green signal time helped to find the durations of the phases. Application of these methods will be helpful in order to solve the traffic organization problems and to increase the traffic safety in the area of Balzac and Kashtanova streets.

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АНАЛІЗ ТРАНСПОРТНОЇ ОРГАНІЗАЦІЇ І ОПТИМІЗАЦІЇ НА ПЕРЕТИНІ ВУЛИЦЬ БАЛЬЗАКА І КАШТАНОВОЇ В КИЄВІ

Анотація
Швидкий розвиток всіх видів транспорту, транспортних комунікацій та збільшення кількості автомобілів в Україні призводить до проблем організації руху і, як наслідок, до високого рівня дорожньо-транспортних пригод. У цій статті основна увага приділяється існуючим проблемам на перетині вулиць Бальзака і Каштановій в Києві. Для поліпшення організації трафіку в існуючій області були реалізовані наступні кроки: створення тривимірної моделі перетину, обчислення проміжного сигналу і визначення часу циклу, визначення фазових розрахунків конкретного напрямку і визначення часу зеленого сигналу. Для врегулювання організації руху на перехресті були запропоновані наступні заходи: введення двофазних світлофорів, встановлення світлофорів для пішоходів і знака «паркування заборонене» з використанням знаків пріоритету. Використовуючи ці стратегії, можна вирішити проблеми організації трафіку і підвищити безпеку руху в цьому районі.

Ключові слова: організація трафіку, безпека руху, 3D-модуляція, перетин.

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АНАЛИЗ ТРАНСПОРТНОЙ ОРГАНИЗАЦИИ И ОПТИМИЗАЦИИ НА ПЕРЕСЕЧЕНИИ УЛИЦ БАЛЬЗАКА И КАШТАНОВОЙ В КИЕВЕ

Аннотация
Быстрое развитие всех видов транспорта, транспортных коммуникаций и увеличение количества автомобилей в Украине приводит к проблемам организации движения и, как следствие, к высокому уровню дорожно-транспортных происшествий. В этой статье основное внимание уделяется существующим проблемам на пересечении улиц Бальзака и Каштановой в Киеве. Для улучшения организации трафика в существующей области были реализованы следующие шаги: создание трехмерной модели пересечения, вычисление промежуточного сигнала и определение времени цикла, определение фазовых расчетов конкретного направления и определение времени зеленого сигнала. Для урегулирования организации движения на перекрестке были предложены следующие меры: ввод двухфазных светофоров, установка светофоров для пешеходов и знака «парковка запрещена» с использованием знаков приоритета. Используя эти стратегии, можно решить проблемы организации трафика и повысить безопасность движения в этом районе.
Ключевые слова: организация трафика, безопасность движения, 3D-модуляция, пересечение.