Evaluation of the traffic signal regulation efficiency of crossroads with unstable transport demand by time

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Abstract. The article describes the results of the research, whose goal is to assess the effectiveness of the traffic light operation at crossroads with unstable transport demand in terms of time and directions. The modern way of cities development consists in creation of sustainable, and, hence, safe, harmless and comfortable environment for residing. This determines the separation of urban and industrial areas, the creation of transport infrastructure, in particular crossroads, which are equipped with traffic lights. As a rule, it is characterized by unstable transport demand in the direction of entry and exit from the territory of enterprises, which causes an inadvertent increase in the idle time of vehicles in the main direction. In the course of experimental studies, the authors found that the crossroads under consideration are parts of the road network that connect the industrial and urban areas, which causes a high traffic intensity in the main areas. At the same time, the share of ineffective resolving phase for entry and exit from the territory of the enterprise reaches 70-80%, which increases the idle time of vehicles in the main direction. The authors proposed an indicator that characterizes the proportion of inefficient operation of the traffic signal.

1 Introduction

The development of road transport contributes to the increase of its park [1-6]. In the Russian Federation for five years the number of operated vehicles has increased by 12.3%. At the same time, according to the Federal State Statistics Service, the density of roads has increased by 11.5%, which indicates a lag in the development of the road network. This causes an increase in the time of vehicle delays, and, consequently, a decrease in the level of comfort in urban areas. The solution of this problem is the sustainable development of a safe, eco-friendly and comfortable urban environment, which necessitates the separation of industrial and urban areas, the development of the transport infrastructure that connects these areas and the reduction in the number of road accidents [7-10].

The growing density of road network and the improvement of road safety lead to an increase in the number of regulation technical means, in particular, traffic lights, which in some cases contribute to the growth of travel time. Therefore, at the present time one of the

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scientific and practical tasks is an increase of the crossroads throughput, which is realized by optimizing the duration of the traffic signal phases and the use of intelligent transport systems. Researches of V.G Zhivoglyadov, A.N Dambrovski, G.I. Klinkovshteyn, J.Lee, S.C. Wong, H. Ceylan suggest the use of genetic and advances algorithms and transport detectors, as methods to optimize traffic light regulation [11-17].

At the present time in the Russian Federation the number of automated traffic management systems exceeds 30,000 units, which is 85% more than in 2010. This development is caused not only by the need to increase the capacity of the road network, but also by the favorable foreign experience of using these systems. This is SCOOT, which is developed and applied in Canada. It manages the operation of traffic lights, detects road accidents, controls the movement of public transport and gives it priority when driving at crossroads. However, intelligent transport system was received the widest application in South Korea. Along with the previously described functions, it monitors the speed of vehicles, makes convenient routes, informs passengers of public transport and drivers about the condition of parking spaces and traffic situation. In the Russian Federation the use of these systems is difficult on a large number of crossroads, which is due to their high cost and complexity of laying communications over long distances. Therefore, increasing the throughput of crossroads that are equipped with traffic lights in accordance with GOST R 522289-2004 is impossible in industrial areas. Their peculiarity consists in the uneven distribution of the traffic flow in time and directions. In the morning and evening hours of the peak there is a high traffic demand, and in the daytime it decreases or is absent in the directions of exits and arrivals to the adjacent territories. This causes an increase in irrational transport delays.

The effectiveness of both unregulated and regulated crossroads is assessed using such criteria as transport delay, number of vehicle stops, fuel consumption, environmental performance, time lost by passengers in route vehicles. In the works [11-13] economic factors, in particular the cost of time lost, are proposed as an indicator of efficiency. However, this stage of research is difficult, due to the high complexity of calculations. Thus, the goal of the study is to assess the effectiveness of the traffic light at crossroads that have unstable transport demand, and the development of a comprehensive indicator for the dissemination of research results.

2 Materials and methods

The purpose of the experiment was assessment of the traffic light effectiveness at an crossroad in the industrial zone and identification of a rational approach to their equipment with technical means of regulation.

The crossroad, which has entrances and exits from the adjacent territory, was chosen as the object of the study. The crossroad scheme is shown in Fig. 1.

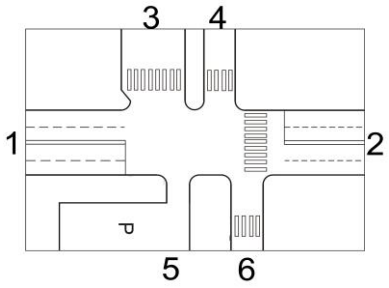

Fig. 1. The scheme of the investigated crossroad.

Main directions (1-2) have four lanes. Directions 3-6 are exits and entrances from adjacent territories and it has 2 lanes.

The traffic light has three-phase regulation, the cyclogram of which is shown in Fig. 2.

Fig. 2. The traffic light control cycle, which is set at the crossroad.

Authors carried out several stages of the experiment to achieve the goal. This is the collection of information about this crossroad, in particular, the traffic pattern, the cyclogram of the regulation of the traffic light. It is processing of the received information, which included the determination of the traffic light phase duration and the number of lanes for movement and their direction. Then the intensity of vehicles movement was determined in directions of 1-6. To do this, researchers considered the number of vehicles that cross the stop line of the crossroad in each direction during peak hours (morning - 7.00-8.00, daytime - 13.00-14.00, evening - 18.00-19.00). Results were recorded in the protocol, which allowed calculating the average traffic intensity of vehicles in directions. At the same time, the number and duration of phases were determined, during which there is no traffic flow in directions 3-6. Based on results of field studies, the proportion of inefficient operation of the traffic light signal was calculated and an indicator was obtained that characterizes the number of phases in which there was no transport demand.

3 Results

The crossroad being investigated is one of the sections that connects the industrial and urban areas. This causes high transport demand in the main directions (1 and 2). Measurements of the traffic intensity in the main directions were carried out to confirm this assumption. The results are shown in Table 1.

Table 1. Results of measuring the traffic intensity of vehicles in the main direction.

Time of day	Number of vehicles passing in the direction, unit/hour	
	2	**1**
07.00-08.00	1000	344
13.00-14.00	836	884
18.00-19.00	1211	994

Depending on the time of day, the change in the traffic intensity in the directions is 30-65%, which is due to the influence of population movement purpose. This is the place of

employment in the morning and this is a resting place in the evening. Stable high transport demand in the main directions (1 and 2) necessitates the predominance over the duration of their resolving signal, which is shown in Figure 2. However, this value is insufficient for an unhindered transit of the crossroad during peak hours. At the same time, analyzing the data obtained during the evaluation of the secondary direction, the authors found that the transport demand from the adjacent territory is small not only in the daytime, but also in the morning and evening. This causes the formation of unresolved resolving phases from directions 3-6. The results are shown in Table 2.

Table 2. The number of resolving phases of the traffic light in directions 3-6 and their time of inefficient operation.

Time of day	Time of inefficient operation of resolving phases in the direction, s/hour		The number of ineffective resolving phases in the direction, unit/hour	
	3,5	**4,6**	**3,5**	**4,6**
6:00-7:00	540	760	18	19
7:00-8:00	510	800	17	20
8:00-9:00	570	720	19	18
9:00-10:00	630	680	21	17
10:00-11:00	600	800	20	20
11:00-12:00	540	760	18	19
12:00-13:00	630	680	21	17
13:00-14:00	540	800	18	20
14:00-15:00	600	720	20	18
15:00-16:00	630	760	21	19
16:00-17:00	570	720	19	18
17:00-18:00	600	680	20	17
18:00-19:00	600	760	20	19
19:00-20:00	630	840	21	21
20:00-21:00	630	840	21	21

The average time of inefficient operation of the resolving phases for directions 3, 5 and 4, 6 is, respectively, 588 s and 755s, or 20, 19 units. Based on the results obtained, the proportion of inefficient operation of the resolving signal in directions 3-6 was calculated, which is shown in Fig. 3.

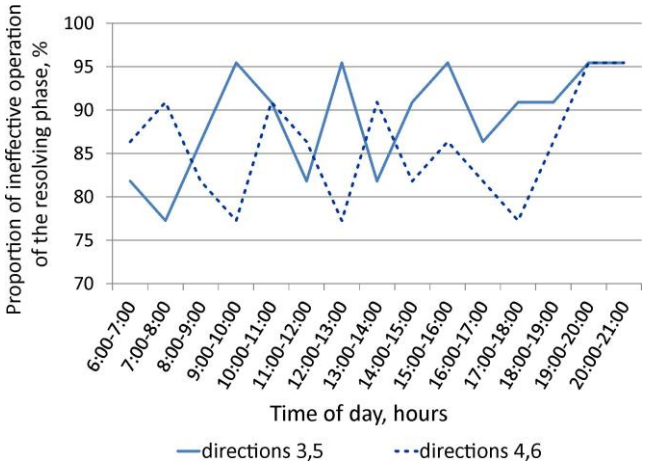

Fig.3. The estimation of the efficiency of the traffic light signal at the crossroad

As a result, the proportion of inefficient operation of the traffic signal at the crossroad is 70-80%. Based on the data obtained, the authors developed an indicator that characterizes the proportion of inefficient phases and is calculated as the ratio of their number to the total number of resolving phases in the direction studied:

$$\eta_{t.r.}=N_{i.r.p}/N_{r.p} \quad (1)$$

where $_{Ni.r.p.}$ – the number of inefficient resolving phases in the determining direction; $N_{r.p}$ – the total number of resolving phases in the determining direction.

For this crossroads, the value of this indicator is 0.89 for directions 3, 5 and it is 0.86 for directions 4, 6. The authors found that with the equality $\eta_{t.r}\geq 0.6$ the traffic control at the crossroad under consideration is not effective

4 Discussions

At the present time, the number of these crossroads is about 7%, however, new approaches in planning the urban environment, in particular the separation of industrial and residential areas, cause a rise this value. It is suggested that the efficiency of these crossroads be estimated using an indicator that characterizes the proportion of inefficient phases and is less labor-intensive in calculation than existing methods. It allows you to extend the results of an experimental study on the other crossing the road network.

The main feature of the crossroads under consideration is the uneven distribution of transport demand over time, which makes it difficult to optimize the traffic light regulation cycle. And the use of intelligent transport systems is an expensive exercise. The solution of this problem is to use a simple system that consists of a video detector and a controller and system switches on the traffic light signal from the adjacent territory only in the presence of vehicles. The development of this system is the next step in improving the efficiency of studied crossroads and the link to create a device that will communicate directly with the onboard computer of the car and allow him to move.

The solving of this problem will not only reduce the indicator that characterizes the proportion of ineffective traffic lights, but also reduce the delay of vehicles, fuel consumption and other technical and economic indicators that are presented in the works of Klinkovshtein G.I., Zhivoglyadov V.G.

Conclusions

In the course of experimental studies, the authors found that the crossroads of the road network, which are the connecting points between the industrial and urban areas, have a high traffic flow intensity and small transport demand when entering and leaving the adjacent territories. This causes a significant number of resolving phases, during which there are no vehicles. The proportion of the resolving phase ineffective operation at these crossroads reaches 70-80%, and the indicator proposed by the authors for estimating the effectiveness of traffic signal regulation is more than 0.6.

The solution of this problem is the development of an adaptive traffic management system that will reduce the time of the resolving signal inefficient operation by applying initially a video detector, and in the future a device that will interact with the vehicle's on-board computer.

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