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RESEARCH ARTICLE

SIMULATION MODELING OF TRAFFIC FOR VARIOUS TYPES OF TRAFFIC LIGHTS REGULATION IN CONDITIONS OF INTENSIVE TRAFFIC OF VEHICLES

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ABSTRACT

The article presents the parameters of traffic with constant, coordinated and adaptive modes of traffic lights regulation in conditions of high traffic intensity of vehicles. Simulation modeling was performed in the Lisa+ program for two intersections of highways in the city of Tobolsk. The initial data are the traffic intensity of vehicles and pedestrians, the geometric parameters of the road and the modes of operation of traffic lights. When integrating the adaptive control mode, the greatest improvement in traffic parameters is observed. It is established that the disadvantage of the adaptive type of regulation is the increase in costs of equipment and construction and installation work.

KEYWORDS

Road network, traffic parameters, adaptive control mode, coordinated type, program complex *Lisa+*.

1. INTRODUCTION

The quality of life in the region and its competitiveness with other territories depends on a large number of factors. One of the important factors is the quality of public transport services. To improve the quality of public transport services, a large number of different groups of actions are applied in large cities and megalopolises. Construction of road infrastructure and infrastructure for public transport, creation of intelligent transport systems (ITS) and automated traffic control systems (ATCS) became the most widespread.

In the last few decades, transport planning and simulation of road traffic have developed around the world. The normative acts regulate the application of these technologies in the development of programs for the development of territories and the choice of the optimal variant for the development of the transport complex [1,2]. Simulation modeling has become widespread at the stage of making pre-project and project decisions [3,4]. The development of information technology, the Internet of things (IoT) and large data (Big Data) allows to increase the accuracy of transport models and modeling, the efficiency of the transport complex, ITS and ATCS. An example is the Dynamic Transport Model of the Moscow Transport Node, created in the state public institution "Centre of the traffic organization" of Moscow.

There is a concept of city public transport services – "Mobility as a service" [5]. An important element of the concept is the refusal to purchase a car, the use of a universal information platform for choosing the best way to move from the point of departure to the destination point by several means of transport. The experience of introduction of paid parking in Moscow showed that a significant part of the population refused to drive their own cars to the city center. Many people have chosen not public transportation, but a taxi or car rental for trips. Load on roads fell, but traffic difficulties during the rush hours remained. Thus, the implementation of ITS, ATCS remains an urgent task for megalopolices [6,7]. Specialists in the design of ATCS are solving the problem of choosing the type of traffic lights regulation. The need to choose the optimal composition of the elements of the ATCS is determined by the customer's requirements for the effective expenditure of funds for its creation.

2. METHODOLOGY

In this paper we estimate the change in traffic parameters for 3 types of regulation: constant, constant with network coordination (hereinafter coordinated) and adaptive control partially dependent on the transport stream (hereinafter adaptive) [8]. With the adaptive type of regulation, the duration of the phases and cycle times in the simulation model changed.
Simulation modeling of the real part of the street-road network of Tobolsk with the use of 3 types of regulation was carried out. Characteristics of the road traffic model: length of the road – 1.6 km, 2 adjustable intersections with traffic lights, total traffic of cars in all directions – 5541 vehicles per hour. The traffic intensity was calculated for each lane of the road, taking into account the further direction of traffic. The general view of the model of one of the intersections in the program complex *Lisa+* is shown in Figure 1.

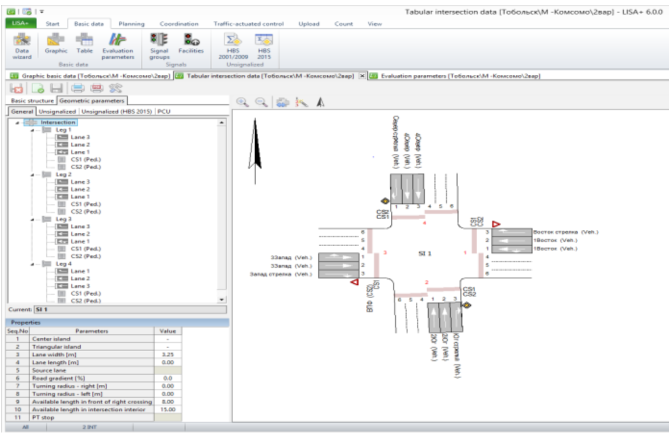

Figure 1: General view of the road's intersection model

3. RESULTS AND DISCUSSION

The current modes of traffic lights operation with a constant type of regulation at the intersections in question are shown in Figure 2, Figure 3. The cycle duration differs and is 172 and 183 seconds.

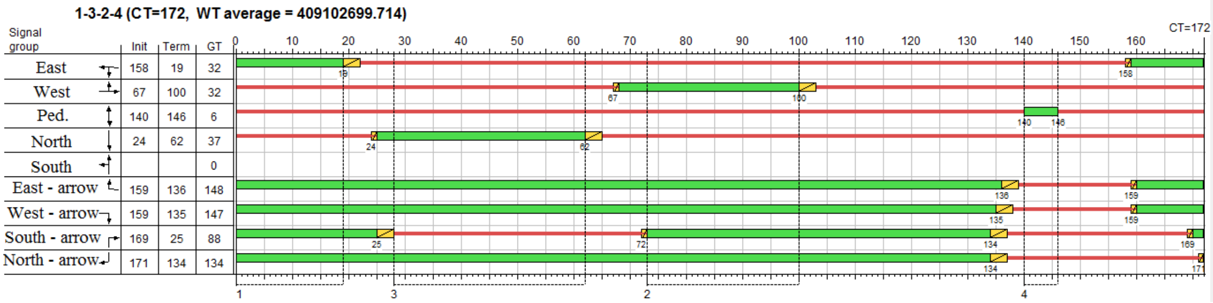

Figure 2: The operating mode of the traffic light object: Mendeleyev Ave. – Komsomolsky Ave.

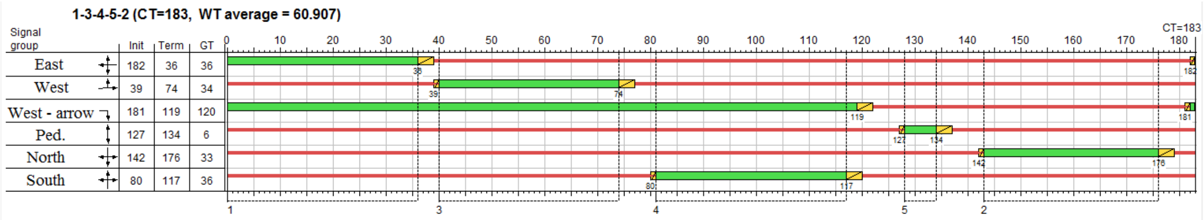

Figure 3: The operating mode of the traffic light object: Mendeleyev Ave. – Yubileynaya str.

The calculation of the optimal cycle time for the traffic light at the intersection of Mendeleyev Ave. – Yubileynaya Str. is made. The graph of the dependence of the delay time on the duration of the cycle is shown in Figure 4. The optimum value is 140 seconds.

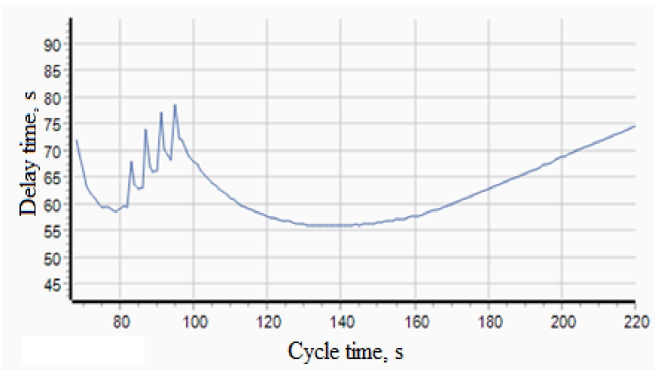

Figure 4: Determination of the optimal cycle time for a traffic light object at the intersection of Mendeleev Ave. – Yubileynaya Str.

When optimizing the mode of a traffic light operation with a constant type of regulation, the parameters will improve, as shown in Table 1. Further, the work performed modeling of traffic in a coordinated, and then adaptive type of traffic light regulation. Traffic parameters for a coordinated type of regulation at particular intersections are given in Table 2, Table 3.

Table 1: Change in traffic parameters, economic and environmental indicators at the intersection of Mendeleyev Ave. – Yubileynaya Str. (constant type of regulation)

Direction of movement of vehicles	Relative change of values, %			
	Excess fuel flow, l/h	Hazardous substances emissions		
		CO, g/h	CH, g/h	NO_x, g/h
East	-11	-13	-12	0
South	-9	-12	-9	0
North	-10	-15	-9	0
West	-11	-14	-11	-5

Table 2: Traffic parameters, economic and environmental indicators at the intersection of Mendeleev Ave. – Yubileynaya Str. (coordinated type)

Direction	Traffic intensity, veh/h	Traffic capacity, veh/h	Average delay time, sec.	Excess fuel flow, * l/h	Hazardous substances emissions, g/h		
					CO	CH	NO_x
East	496	685	58,9	15,3	2600	0,37	0,23
South	548	1000	57,7	16,6	2800	0,41	0,25
West	752	1759	41,9	17,5	2900	0,43	0,27
North	449	618	60,6	14,1	2400	0,34	0,21

*Note. Excess fuel flow in the program Lisa+ corresponds to the hourly fuel consumption of the car while the vehicle is in a jam without moving.

After the transition to the coordinated regulation, there is an improvement in indicators. The duration of the traffic light cycle is reduced to 140 seconds at both intersections. Figure 5 and Figure 6 show the operation modes of traffic lights for a coordinated type of regulation.

Table 3: Traffic parameters, economic and environmental indicators at the intersection of Mendeleev Ave. – Komsomolsky Ave. (coordinated type)

Direction	Traffic intensity, veh/h	Traffic capacity, veh/h	Average delay time, sec.	Excess fuel flow, * l/h	Hazardous substances emissions, g/h		
					CO	CH	NO_x
East	862	2247	36,3	17,9	3000	0,44	0,29
South	927	2303	35,1	18,7	3100	0,46	0,30
West	772	2280	40,8	17,8	3000	0,44	0,28
North	735	2503	28,9	13,1	2100	0,32	0,23

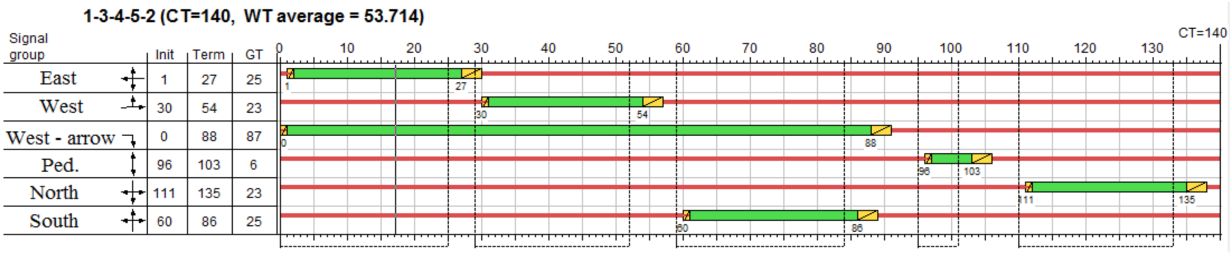

Figure 5: Design operation mode of the Mendeleyev Ave. – Yubileynaya Str. traffic light object (coordinated type of regulation)

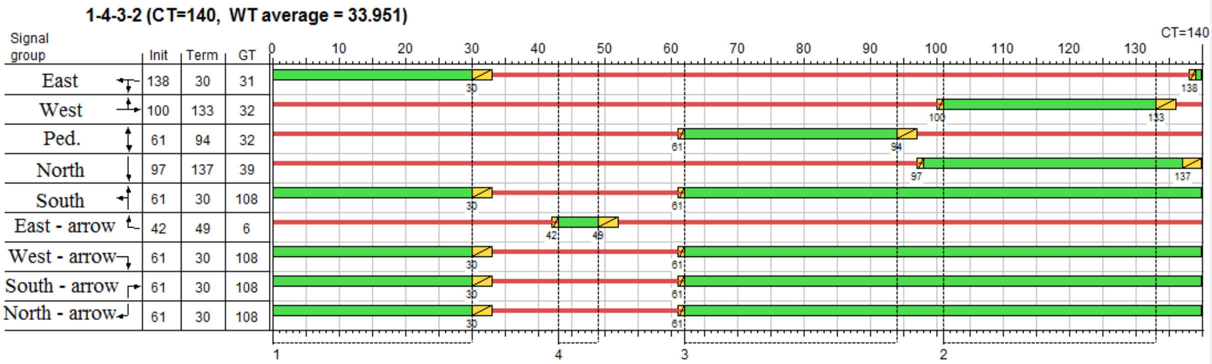

Figure 6: Design operation mode of the Mendeleyev Ave. – Komsomolsky Ave. traffic light object (coordinated type of regulation)

The values of the indicators for the model as a whole for various types of regulation of the traffic light object are given in Table 4. For specific transport and road conditions, the best traffic parameters of the three types of regulation of traffic light objects are achieved with an adaptive type of regulation. For a more detailed analysis of changes in motion parameters, it is necessary to import the model from the Lisa+ program into PTV Vissim.

Table 4: Traffic parameters, economic and environmental indicators within the boundaries of the modeling object (for 2 intersections)

Type of the traffic light regulation	Total traffic capacity of 2 nodes, veh/h	Average delay time, sec.	Excess fuel flow, l/h	Hazardous substances emissions, g/h		
				CO	CH	NO_x
constant	14363	425,2	140,7	24400	3,43	2,76
coordinated	13395	360,2	131,0	21900	3,21	2,06
adaptive	10180	273,8	99,6	16644	2,4	1,6

When implementing the adaptive type of regulation by two traffic lights, the traffic parameters, environmental and economic indicators are improved: the average delay time is reduced by 35.7%, excess fuel flow is reduced by 29.2%, the amount of harmful substances with exhaust gases of ICE is reduced by 31.8%. The economic effect of reducing the costs of car owners for fuel is about 1562 rubles for 1 hour with the current traffic intensity (at an average cost of fuel equal to 38 rubles per 1 liter). On an annual basis, saving fuel costs for 1 hour (for 250 working days) is 390,500 rubles.

4. CONCLUSION

For this simulation object, the key factor in the effectiveness of adaptive regulation is the distance between road intersections (510 m). A sufficient distance between the intersections leads to discontinuities in the transport stream. This allows transferring the priority of movement to another direction. At a small distance between the intersections, another type of regulation can be optimal.

The disadvantage of the adaptive type of regulation is the increase in costs of equipment and construction and installation work. Creation of ATCS in the cities requires fewer expenses in comparison with the construction of expensive road infrastructure facilities. In the central part of the city in dense housing conditions, ATCS creation can be the only possible measure to improve traffic.

Simulation modeling of road traffic allows determining the most effective way to control a traffic light object at the decision-making stage. At the next stage of the study, it is planned to develop a multifactor model of traffic parameters taking into account changes in transport and road conditions. For the practical use of the results of the study, it is planned to make a Methodology for assessing the efficiency of the ATCS creation at the decision-making stage.

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