Change of Traffic Parameters when Introduced Adaptive Method of Traffic Light Object Control

Dmitriy Karmanov[1*], *Dmitriy* Zakharov[1], and *Andrey* Chistyakov[1]

[1]Tyumen Industrial University, 38 Volodarskogo str, Tyumen, 625000, Russia

Abstract. The article is devoted to improving the quality of life in cities by implementing the concept of an "intelligent" city and developing an automated transport infrastructure. The following factors are considered in the work: the traffic intensity of vehicles and the mode of operation of traffic signal regulation. In work, the mode of operation of a traffic light is determined by an adaptive method. The main tool for increasing the capacity is the choice of the optimal ratio of phase coefficients and the optimal cycle time. Considered the influence of capacity on the parameters of road traffic, the environmental load from automobile transport. The dependence of the traffic parameters for different cycle times is established. A change in fuel consumption and in the content of harmful emissions for various traffic light modes is given. The justification is given for the necessity to change the traffic light mode after increasing the number of lanes in the street road network.

1 Introduction

Improving the quality of transport services for the population of cities is an important task for municipal authorities.

Experts note a significant lag in the development of the street-road network (SRN) of Russian cities in comparison with the cities of Europe and the United States [1]. On average, this gap is 3-4 times.

In cities of Russia, municipal authorities have to solve 3 tasks to improve the quality of transport services for the population: to develop road infrastructure, public transport and improve traffic management systems.

One of the ways to improve the quality of traffic management is the introduction of intelligent transport systems (ITS) and its individual elements, such as an automated traffic management system (ATMS).

At the stage of deciding on the choice of measures to improve the quality of transport services to the customer (municipal authorities), there is a need to evaluate the effectiveness of spending budget funds, compare with other measures to increase the capacity of the road network [2, 3].

The possibility of comparing the variants of the development of the urban transport complex with the choice of priorities in road construction or the development of public

* Corresponding author: numlock10@mail.ru

© The Authors, published by EDP Sciences. This is an open access article distributed under the terms of the Creative Commons Attribution License 4.0 (http://creativecommons.org/licenses/by/4.0/).

transport allows imitating modeling and the creation of a transport model of the city and region (macro-level modeling) [1,3,4].

Comparison of options for the reconstruction of the road network and the selection of the most efficient of them is carried out by means of micro-level modelling [4,5].

Less common is the task of assessing the effectiveness of creating an automated traffic management system as a element of ITS. In total ITS influence not only on the traffic flow characteristics but also on safety [6,7,8,9,10].

2 Material and methods

Lisa+ software were obtained for this experiment. To create imitation transport model initial data obtained experimentally.

3 Experimental part. Determining the optimal cycle time

The purpose of the study is to create a methodology for assessing the effectiveness of the creation of the ATMS at the decision-making stage.

A mathematical model in the general form of the influence of SRN parameters, distances between intersections, traffic intensity during the operation of traffic light objects in the "hard mode" on the parameters of traffic has been developed.

In general, the model has the form:

$$ts = t0 \cdot k \cdot \Delta\varphi + t0 \cdot \frac{n}{Na} + t0 \cdot \frac{l}{Lsp}, \qquad (1)$$

$$V = \frac{Lsp}{t0 - \Delta\varphi} + \frac{Lsp}{t0 \cdot Na} + V0 + \frac{Lsp}{t0}, \qquad (2)$$

where ts - waiting time, sec;
$t0$ –average delay time for 1 vehicle, sec;
k – correction factor;
$\Delta\varphi$ – the magnitude of the time shift of traffic lights, sec;
n – correction factor;
Na – traffic intensity, Veh/h;
l - correction factor;
Lsp – space interval length, m;
V – travel speed, km/h;
$V0$ - average speed for 1 vehicle, km/h.

3.1 Collection of source data

In work, for example of crossing two main streets - st. 50 years of October and st. Profsoyuznaya (figure 1), is examined the issue of determining the optimal cycle time (CT). Experimentally, intensity was obtained for the morning peak hour (Figure 2), the mode of operation of the traffic light object (Figure 3).

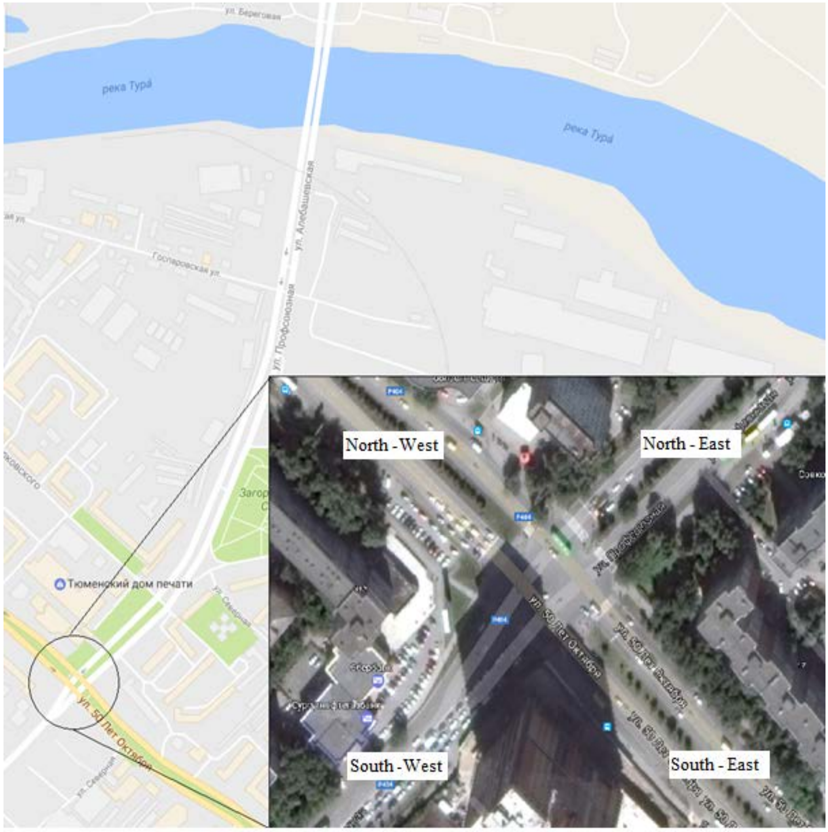

Fig. 1. Considered intersection.

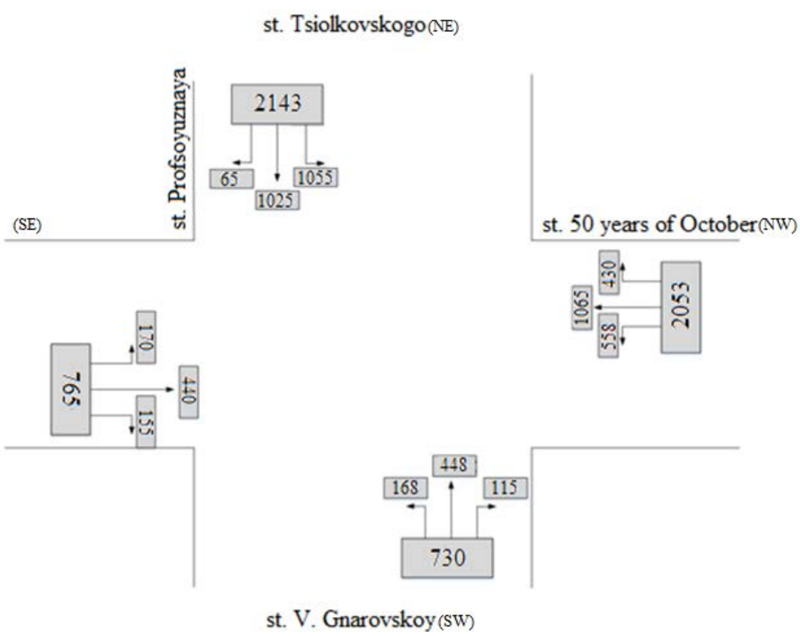

Fig. 2. Cartogram of intensity of morning rush hour of intersection st. 50 years of October - st. Profsoyuznaya.

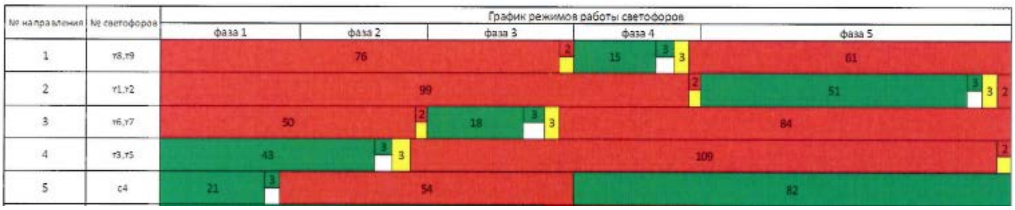

Fig. 3. Current mode of operation of set of traffic lights.

Table 1 shows the values of the parameters for current mode, as capacity, volume of traffic, loading level and phase coefficient.

Table 1. Intersection loading level.

Direction	Lane №	Volume of traffic, Veh/h		Capacity, Veh/h		Loading level	Phase coefficient	
		Lane	Direction	Lane	Direction		Lane	Direction
NE	1	383	1973	483	2073	0,95	0,34	0,34
	2	483		483			0,34	
	3	556		556			0,34	
	4	551		551			0,34	
SW	1	191	584	191	584	1	0,13	0,13
	2	202		202			0,13	
	3	191		191			0,13	
NW	1	155	712	162	719	0,99	0,11	0,11
	2	191		191			0,11	
	3	191		191			0,11	
	4	175		175			0,11	
SE	1	430	1606	1037	2213	0,73	0,66	0,29
	2	506		506			0,29	
	3	506		506			0,29	
	4	164		164			0,29	
Total:		4875		5589		0,92		

As the parameters values show, considered intersection is overload. The whole intersection do not cope with that volume of traffic level. This node of road network effect on the immediate intersections and has an important purpose because it's one of the four possibly ways to the other part of the city.

3.2 Experimental part

To create a simulation model, the Lisa+ software package is used.

The first step is creation fixed cycle time, according to current (cycle time = 160 sec) to understand the functioning of the automatic distribution of the phase coefficient (figure 4). Table 2 shows intersection loading level after optimization.

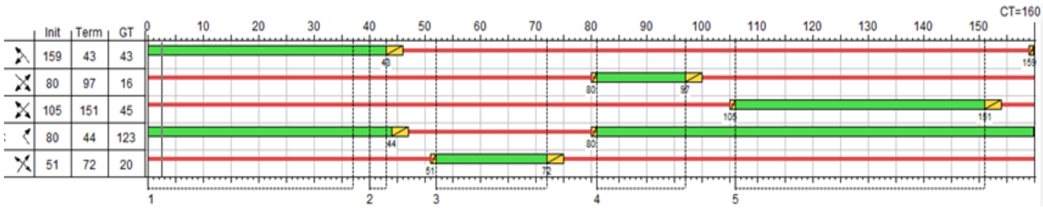

Fig. 4. Optimized cycle (CT = 160 sec).

Table 2. Intersection loading level after optimization (CT = 160 sec).

Direction	Lane №	Volume of traffic, Veh/h		Capacity, Veh/h		Loading level	Phase coefficient	
		Lane	Direction	Lane	Direction		Lane	Direction
NE	1	383	2008	506	2131	0,94	0,33	0,33
	2	506		506			0,33	
	3	563		563			0,33	
	4	556		556			0,33	
SW	1	238	720	238	720	1,00	0,13	0,13
	2	250		250			0,13	
	3	232		232			0,13	
NW	1	155	738	183	766	0,96	0,12	0,12
	2	200		200			0,12	
	3	200		200			0,12	
	4	183		183			0,12	
SE	1	430	1974	1384	2928	0,7	0,81	0,31
	2	528		528			0,31	
	3	532		532			0,31	
	4	484		484			0,31	
Total:		5440		6545		0,9	-	

Also, the optimal cycle time was calculated, according to the criterion of minimizing the delay time, without limitations of the total cycle time. Traffic signalization is not coordinated, therefore the cycle time amounted to 243 seconds (figure 5). Table 3 shows intersection loading.

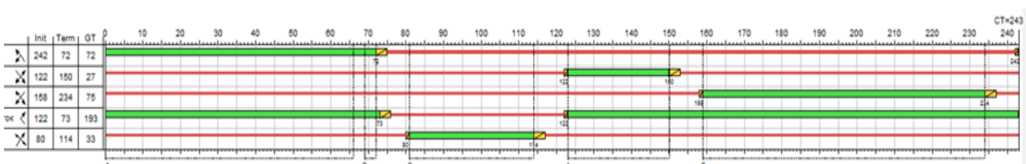

Fig. 5. Optimized cycle (CT = 243 sec).

The distribution of the phase coefficient to the required directions has a positive effect on the capacity and transport flow parameters.

The increase in capacity on the main street will allow to obtain a complex effect in several directions:

- ecological (reduction of emissions of harmful substances with exhaust gases of cars) [11,12];
- socio-economic (saving time, fuel consumption) [13].

Table 3. Intersection loading level after optimization (CT = 243 sec).

Direction	Lane №	Volume of traffic, Veh/h		Capacity, Veh/h		Loading level	Phase coefficient	
		Lane	Direction	Lane	Direction		Lane	Direction
NE	1	515	2145	610	2339	0,92	0,31	0,31
	2	575		617			0,31	
	3	527		556			0,31	
	4	528		556			0,31	
SW	1	238	730	259	783	0,93	0,14	0,14
	2	260		272			0,14	
	3	232		252			0,14	
NW	1	155	765	204	848	0,9	0,11	0,11
	2	210		222			0,11	
	3	210		222			0,11	
	4	190		200			0,11	
SE	1	430	2053	1430	3143	0,7	0,79	0,3
	2	562		593			0,3	
	3	549		587			0,3	
	4	512		533			0,3	
Total:		5693		7113		0,86	-	

The change in several environmental and socioeconomic parameters is shown in Table 4.

Table 4. The values of the traffic parameters and the environmental load for a different cycle time

Parameters	CT = 160	CT = 243	Absolute deviation	Relative deviation, %
Average waiting time (sec)	182,1	108,2	-73,9	-41
Number of stopping vehicles per hour	5394	5342	-52	-1
Capacity (Veh/h)	5694	7113	1419	25
Excess fuel consumption (l/h)	383,1	255,9	-127,2	-33
CO (kg/h)	77,1	48,6	-28,5	-37
CH (g/h)	9,4	6,3	-3,1	-33
Nox (g/h)	3	2,7	-0,3	-11
Flow	5694	5694	0	0

Figure 6 is a graph showing the change in the average delay time per vehicle, depending on the cycle duration.

Fig. 6. Changing the delay time depending on the change in the time of the traffic signal regulation cycle

Adaptive control contributes to the increase of traffic flow rates, reduction of noise load and emissions of harmful substances into the atmosphere of the city [14], allow to develop intelligent concept for providing priority to public transport [15].

4 Results

It is established that for the considered intersection at a cycle time of 160 seconds, the ratio of phase coefficients is not optimal. It was determined that the best traffic parameters are achieved with a cycle time of 243 seconds. Adaptive management allows to determine the optimal mode of traffic light traffic with the least time and labor costs.

5 Conclusion

The theoretical and experimental studies carried out by the authors established the influence of the length of the traffic regulation cycle on the capacity, traffic parameters, fuel consumption and the amount of emissions of harmful substances into the atmosphere. This allowed us to formulate recommendations for choosing the optimal duration of the cycle and the ratio of the phase coefficients. Further research is expected to develop a methodology for assessing the effectiveness of the creation of the ATMS.

The introduction of the results of the research will allow to reduce fuel consumption, the content of harmful substances in the exhaust gases, improve the traffic flow conditions.

References

1. *Methodological support to the Preparation of National and Regional Transport Plans and the related Ex-Ante-Conditionality to the 2014-2020 Programming Period*: JASPERS (2014)
2. *National ITS Architecture*. *Physical Architecture*. www.iteris.com/itsarch/index.htm
3. *Robin Williams Intelligent Transport Systems Standards Artech house* (2008)
4. J. Ortuzar, L. Willumsen, *Modeling Transport* / 3-rd edition. – John Willey and Sons Ltd (2008)

5. V. Zyryanov, *Simulation of impact of components of ITS on congested traffic states* Proc. 7th Europ. Congr. Intell. Transp. Syst.: ITS for Sustainable Mobility. Geneve, Switzerland (2008)
6. O. Carsten, F. Tate, *Intelligent speed adaptation: accident savings and cost-benefit analysis*, Accident Analysis & Prevention, **37, 3**, pp 407-416 (2005)
7. M. Karlaftis, S. Latoski, N. Richards, K. Sinha, *ITS Impacts on safety and traffic management*: *An investigation of secondary crash causes*. ITS Journal, pp 39-52 (1999)
8. G. Giuliano, *Incident Characteristics, Frequency, and Duration on a High Volume Urban Freeway*. Transportation Research Part A, pp 387-396 (1989)
9. M. Deakin, H. Al Waer, *From intelligent to smart cities*. Intelligent Buildings International, **3**, pp 140-152 (2011)
10. *Safety Evaluation of Intelligent Transportation Systems*. Workshop Proceedings. Reston Virginia (1995)
11. M. De Blasiis, M. Di Prete, C. Guattari, V. Veraldi, G. Chiatti, F. Palmieri. *Investigating The Influence Of Highway Traffic Flow Condition On Pollutant Emissions Using Driving Simulators* , Air Pollution XXI, pp. 171-181 (2013)
12. S. Boubakera, F. Rehimia, A. Kalboussib, *Impact of intersection type and a vehicular fleet's hybridization level on energy consumption and emissions*, Journal of Traffic and Transportation Engineering (English Edition), **3,** pp. 253-261 (2016)
13. S. Grava, *Urban transportation systems*. *Choices for communities*, McGraw-Hill; (2003)
14. M. Sundeen, *The Expanding Role of Intelligent Transportation Systems* , National Conference of State Legislatures (2002)
15. K. Balke, D. Urbanik, L. Conrad, Development *and Evaluation of Intelligent Bus Priority Concept* , Transp. Res. Rec. (2000)