Section: Research Paper

REDUCING VEHICLE EXHAUST GASES BY COMPUTER SIMULATION OF THE ROAD INTERSECTION

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Annotation: This article presents the results of developing an intersection model using the PTV VISSIM simulation program. One of the problematic intersections in the city of Tashkent was selected and the traffic flow at peak hours according to congestion was studied to simulate the intersection. The article discusses two solutions to reduce the amount of toxic gases and fuel consumption. The first solution represents a reduction through the optimization of traffic light phases and a change in the junction control cycle. The second solution represents the reduction through changes in the geometrical parameters of the intersection. After applying the two solutions, the level of service LOS at the intersection improved from F to B.

Key words: intersection model, simulation program, traffic flow, rush hour, toxic gases, fuel consumption, regulation phase, regulation cycle, service level at the intersection.

In recent years, the number of cars has increased by 2-3 times, and about 700-800 thousand cars drive on the streets of the city every day. In addition to creating congestion, they cause environmental degradation, the safety of pedestrians and passengers. But the city's public transport and road infrastructure cannot adequately meet these challenges. The city lacks over ground and underground pedestrian crossings and parking lots. There are also over 500 large intersections in the city, and 200 of them have low vehicle throughput.

Atmospheric pollution by operated cars is very high, for example, when one car consumes 10-12 liters of gasoline, 25 kg of various harmful chemical compounds are released into the atmosphere. One car consumes about 4 tons of oxygen per year [2]. Engine exhaust gas contains more than 500 harmful organic compounds such as carbon monoxide (CO), carbonate anhydride (CO2), nitric oxide (NO), hydrocarbons (HC), volatile organic components (VOC), etc. All this becomes the reason for the deterioration of human health and global warming around the world [1]. Optimal organization of traffic lights at intersections reduces these emissions. Traffic jams are sources of harmful emissions. Studies show that drivers, passengers and people living near highways will suffer the most from this. Sometimes their impact ends in a fatal outcome. Since 2019, Yandex in Uzbekistan has begun to inform about traffic jams in the city. After 11 months of work, the company summed up the results of the year and determined how traffic jams in the city of Tashkent are changing. The average traffic jam has changed from 4.5 points in August to 5.8 points in April. If the most convenient time of the year for car owners is summer, then the most difficult time is the morning traffic jam in April.

An intersection in the city center with the intersection of University, Bogishamol and the Great Tashkent Ring Road was chosen as the object of research. General street data is shown below. The number of lanes of University street 5, the width of the street is 21 m, there are dividing lanes and pedestrian crossings on the street; the number of lanes of Bogishamol street 6, the width of the street is 25 m, there are dividing lanes and pedestrian crossings on the street; the number of lanes of the Tashkent ring road near the intersection 5, the width of the streets on one side is 22 m and on the other 25 m, there are dividing lanes and pedestrian crossings on the street. The traffic light works on 2 phases. The duration of the traffic light cycle is 98 seconds. On fig. 1 shows a view of the intersection under study.

Fig.1. General view of the intersection

Table 1 shows the number of vehicles by type passing through the intersection in 2 hours.

Table 1

Vehicle types	**A car**	**Bus**	**Freight car**
Quantity	12639	294	687

Based on the above data, a simulation model of the current state of the intersection was developed using the PTV VISSIM program. The quality of the throughput of the intersection is estimated as follows (Table 2).

Table 2.

LOS	**For an intersection controlled by a traffic light**	**For an intersection controlled without a traffic light**
A	≤10 s	≤10 s
B	10–20 s	10–15 s
C	20–35 s	15–25 s
D	35–55 s	25–35 s
E	55–80 s	35–50 s
F	>80 s	>50 s

For regulated and unregulated intersections, LOS is determined by the average vehicle delay at the intersection. LOS can be defined for each intersection configuration, for each movement or approach.

Fig.2. Digital twin of the current state of the investigated intersection

A computer model of the current state of the intersection has been developed, taking into account the traffic flow, traffic light phases and cycle duration, and the following results have been obtained (Table 3).

Table 3

№	Options	Current state
1.	Level of service at the intersection (LOS)	**F**
2.	Number of vehicles (piece)	**5317**
3.	Fuel consumption (L)	**1067,959**
4.	Exhaust gas CO (grams)	**19720,533**
5.	Nitric oxide NOx (grams)	**3836,899**
6.	Organic compounds VOC (grams)	**4570,424**

Currently, traffic lights have been installed at the intersection, which operate in two phases and have a cycle time of 98 seconds. The effective green traffic light period is 92 seconds and the lost time is 6 seconds.

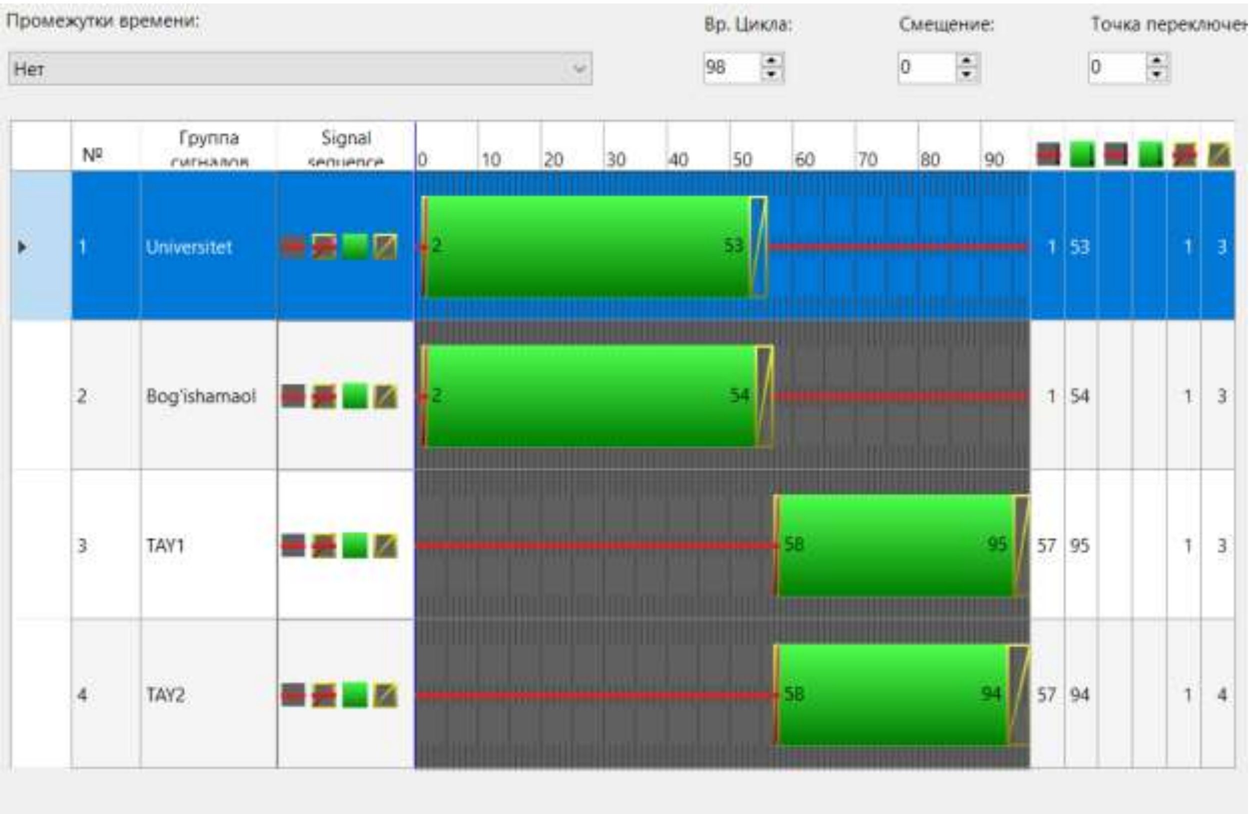

Fig. 3. Computer model of the cycle and phase of a traffic light installed at an intersection.

For the intersection of Universitet, Bogishamol and the Great Tashkent Ring Road, the rational duration of the cycle is determined as follows.

Proposed traffic light phase and cycle

Table 4

	Phase A	**Phase B**
v	648/3=216	1246/2=623
s	1400	1400
v/s	**0.28**	**0.41**

A computer model of the intersection has been built, taking into account the proposed phase and traffic light cycle values. After computer simulation, the following results are obtained. The optimal value of the duration of the control cycle is determined by the Webster formula [4].

$$C = \frac{(1,5L + 5)}{1 - Y_c}$$

where C is the duration of the control cycle, s;

L is the lost time per cycle, s;

Y_c - the sum of critical v/s - ratios (phase coefficients) Using the data in Table 4, the calculation was made and the following results were obtained:

Y_c = 0,15+0,44=0,59; L= 6 c,

C = (1,5*6+5)/(1-0,59) = 34 c.

Fig. 4. The proposed computer model of the intersection

From Table 5, one can see the improved throughput of the intersection by several times due to the optimization of the phase and cycle of the traffic light installed at the intersection.

Geometric changes at this intersection make it possible to minimize the number of traffic light phases, reduce conflict points and delay the car at it.

Proposed indicators obtained as a result of computer simulation

Table 5

№	Options	Current state
1.	Level of service at the intersection (LOS)	B
2.	Number of vehicles (piece)	7598
3.	Fuel consumption (L)	608,773
4.	Exhaust gas CO (grams)	11241,364
5.	Nitric oxide NOx (grams)	2187,161
6.	Organic compounds VOC (grams)	2605,295

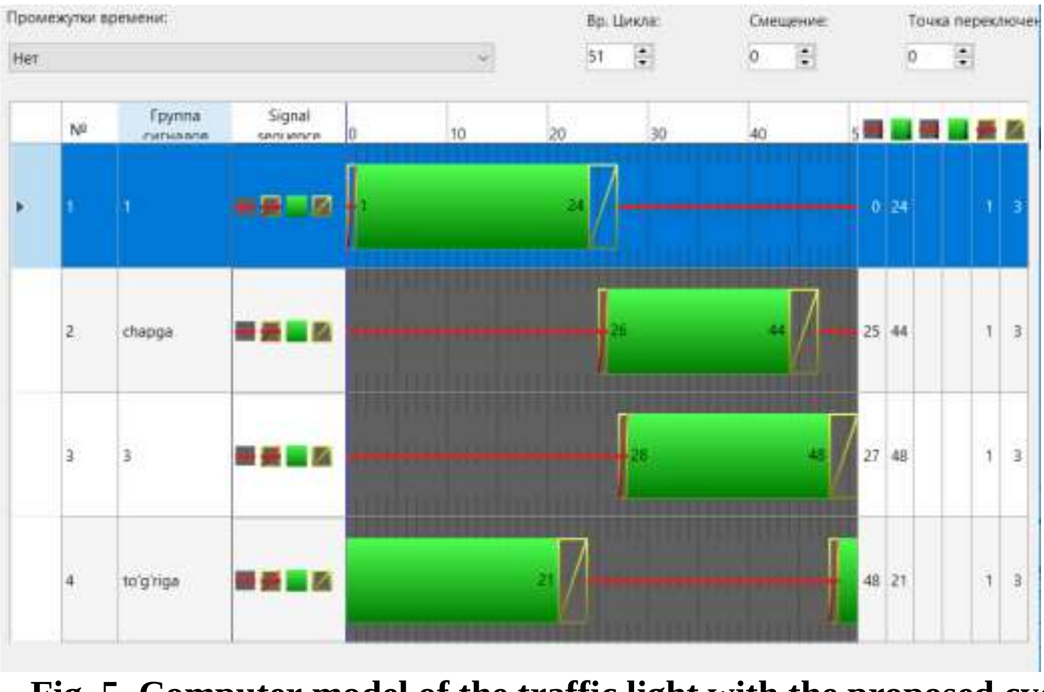

Fig. 5. Computer model of the traffic light with the proposed cycle and phases.

To meet the requirements of the traffic flow, a sufficient level of capacity is estimated by the critical ratio Xc (v/c, v-traffic intensity; c-crossroad capacity). If the v/c ratio is below 0.85 as usual, then the required capacity is provided, i.e., no delays or downtime of vehicles are observed. When the v/c ratio approaches 1.0, the traffic flow becomes unstable, delays and congestion are observed. When the v/c ratio is greater than 1.0, demand exceeds capacity, traffic becomes erratic, there is a strong delay and large traffic jams occur. Under such conditions, vehicles in order to pass the intersection will wait several traffic light cycles and a cycle failure occurs. When modeling intersections for long-term prospects (for 20 years) for peak hours, it is advisable to proceed from the conditions when the values of v/c ratios are from 0.85 to 0.95 [4].

The PTV VISSIM program can be used to determine the solution for effective street traffic management. Usually 15 minutes of analysis for each vehicle is sufficient,

to determine the given data for the whole day. After simulating the state of the intersection with changed parameters, the following results were obtained:

- throughput capacity of the intersection for one hour at peak times;
- maximum length of traffic jam formed at the intersection;
- average delay of the vehicle;
- vehicle fuel consumption;
- Loss of Service at an Intersection (LOS);
- amount of air emissions from vehicles.

№	Options	Current state	Proposed state
1	Level of service at the intersection (LOS)	F	B
2	Number of vehicles (piece)	5317	7598
3	Fuel consumption (L)	1067,843	608,773
4	Exhaust gas CO (grams)	19720,533	11241,364
5	Nitric oxide NOx (grams)	3836,899	2187,161
6	Organic compounds VOC (grams)	4570,424	2605,295

The results of the computer model for optimizing the operation of the intersection are shown in Table 5. From the table, it can be observed that the service level of the intersection is improved from F to B. Vehicle emissions and fuel consumption are reduced by almost 50%. In other parameters, too, you can see a significant improvement. The results were achieved thanks to a computer model of the intersection developed using the PTV VISSIM simulation program.

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