SAT-ONLINE-1-SITST-5

IMPROVING THE PASSING CONDITIONS THROUGH A CROSSROADS IN THE CITY OF SOFIA WITH HIGH TRANSPORT LOADS[1]

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Abstract: *The main purpose of the publication is to present one of the possible options for improving the conditions of passing through an intersection with high traffic load. The option for implementation of traffic lights at a specific intersection in the city of Sofia, regulated with road signs for priority, has been assessed. Public transport vehicles also pass through the intersection, which is the reason for changing the road with an advantage in it. This is one of the prerequisites, given the intensity of incoming traffic flows, for the formation of queues of cars in the peak periods of the day, which interfere with its normal functioning. Implementation of the decision to implement traffic lights is expected to achieve benefits of different nature in environmental, psychological and time-saving terms.*

Keywords: *Traffic flows, Traffic research, Traffic lights, waiting time.*

INTRODUCTION

Traffic regulation provides the necessary separation of transport flows over time at intersecting trajectories. Proper application of the possible options for this ensures the safety of cars passing through intersections with minimal loss of time for passengers.

The choice of the appropriate variant of traffic regulation needs to be based on research related to the main indicators of traffic flows, where their intensity is decisive. It is imperative to conduct research related to traffic capacity, delays (Guler S., 2016) and queue lengths that are formed at the entrances of intersections (Ma D., etc., 2012). The data in the research need to recorded in special forms (Todorov, T. 1982), the set of parameters is must to analyzed, the type of regulation is determined and the interaction between transport flows and other (pedestrian, bicycle) flows that pass through the intersection is assessed (Damyanov, I., etc. 2017, pp 118-121).

Implement of the traffic light regulation is based on criteria laid down in the legislation of the Republic of Bulgaria (Ministry of Regional Development and Public Works, Ordinance № 17, 2015). The trend in traffic light regulation is to provide opportunities for real-time system control with data from incoming and outgoing traffic flows. In world practice, different possibilities for achieving this

[1]Докладът е представен на научна сесия на 30 октомври 2021 с оригинално заглавие на български език: ПОДОБРЯВАНЕ УСЛОВИЯТА ЗА ПРЕМИНАВАНЕ ПРЕЗ КРЪСТОВИЩЕ В ГРАД СОФИЯ С ГОЛЯМО ТРАНСПОРТНО НАТОВАРВАНЕ

goal are evaluated (Kareem T., Jabbar M., 2018, Fangzhou Q., Yang J., 2015, Alaidi A., etc., 2020), whereby the benefits of different character are reached.

In the present publication the variant for mounting of traffic light regulation at the intersection regulated with road signs for priority is evaluated. The considered crossroads is one of the extremely busy on the territory of "Student City" district in the city of Sofia. The assessment uses a methodology presented in 2017, which is an algorithm for determining the duration of the traffic light cycle, which is based on the intensity of traffic flows, the throughput of the elements of the intersection and the period of the day of which these values relate (Saliev D., 2017, pp. 33-34).

EXPOSITION

The object of study is a four-entrance crossroads between the streets "Acad. Boris Stefanov" and "Prof. Dr. Ivan Stranski". A scheme of the intersection is shown in Fig. 1.

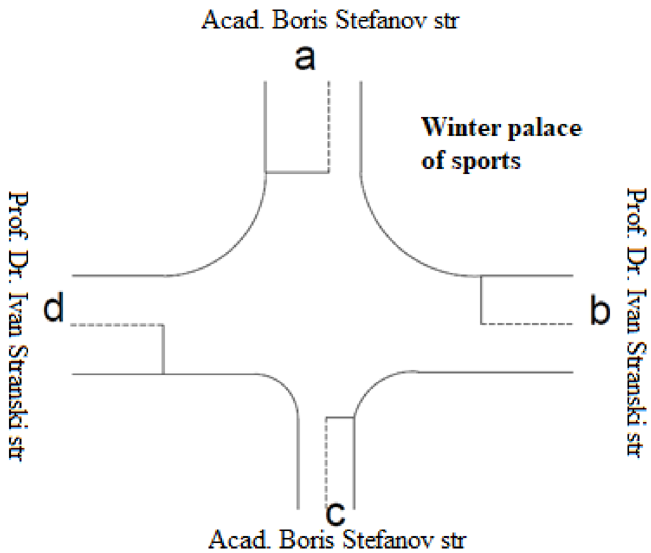

Fig. 1. A scheme of the intersection between streets "Acad. Boris Stefanov" and "Prof. Dr. Ivan Stranski"

The intersection is regulated with road signs, with approach "a" and approach "b" being preferred. The size of the incoming approachess are as follows

Approach "a" - road 10,4 m; entrance road line 7 m and exit road line 3,4 m;
Approach "b" - road 10,5 m; lanes of 5.25 m each;
Approach "c" - road 6,2 m; lines of 3,1 m each;
Approach "d" - road 10,7 m; lines of 5,35 m each;

The expediency of installation traffic lights at the selected intersection can be determined on the basis of research conducted during one hour during in the morning, noon and evening peak periods of the day.

For the considered intersection on "Acad. Boris Stefanov"and "Prof. Dr. Ivan Stranski" in the days from Tuesday to Thursday, in the period from 07:00 to 22:00, the traffic was examined to establish its intensity. For the purposes of the studies, the traffic flows passing through the junction were numbered as follows:

Traffic flow 1: a – d;
Traffic flow 2: a – c;
Traffic flow 3: a – b;
Traffic flow 4: b – a;
Traffic flow 5: b – d;
Traffic flow 6: b – c;
Traffic flow 7: c – b;

Traffic flow 8: c – a;
Traffic flow 9: c – d;
Traffic flow 10: d – c;
Traffic flow 11: d – b;
Traffic flow 12: d – a;

The transport flows are presented graphically in Fig. 2. The obtained intensity data give grounds to determine three periods of the day in which the traffic can be organized with different duration of the traffic light cycle. The first period is from 7 to 13 hours, the second period is from 13 to 18 hours and the last is from 18 to 22 hours, and for each of them the intensity of traffic flows is determined. The results of the studies for the morning, noon and evening peaks are shown in Table 1.

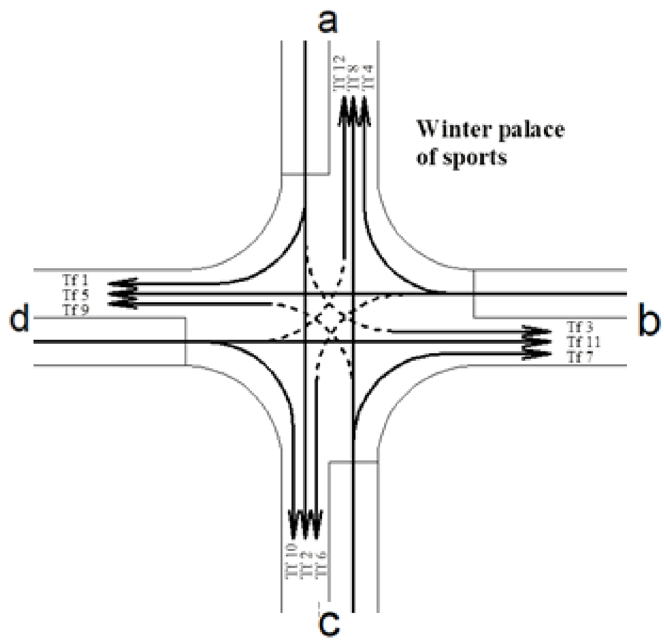

Fig.2. A scheme of transport flows of the intersection between streets "Acad. Boris Stefanov" and "Prof. Dr. Ivan Stranski"

Table 1. Intensity of traffic flows by period of day

Traffic flow №	Indensity [I_a^f] by period of the day, veh/s		
	7-13	13-18	18-22
Traffic flow 1: a – d	0,066	0,101	0,117
Traffic flow 2: a – c	0,002	0,005	0,006
Traffic flow 3: a – b	0,013	0,032	0,024
Traffic flow 4: b – a	0,021	0,025	0,032
Traffic flow 5: b – d	0,092	0,093	0,113
Traffic flow 6: b – c	0,004	0,006	0,009
Traffic flow 7: c – b	0,011	0,006	0,012
Traffic flow 8: c – a	0,001	0,002	0,005
Traffic flow 9: c – d	0,011	0,004	0,008
Traffic flow 10: d – c	0,004	0,005	0,007
Traffic flow 11: d – b	0,150	0,105	0,156
Traffic flow 12: d – a	0,050	0,076	0,077

The geometric dimensions of the intersection allow to change the number and width of the road lanes at the entrances and exits of the intersection in order to optimize the passage of traffic flows passing through it. The following changes are proposed:

Approach "a" to have three lanes, two entrance and one exit, with a lane width of 3.40 m.

Approach “b” should have three lanes, two entrance and one exit, with a lane width of 3.50 m.
Approach “c” to remain with two lanes due to low intensity.
Approach “d” to have three lanes, two entrance and one exit, with a lane width of 3.50 m.
Figure 3 shows the redistribution of the road lanes at the intersection.

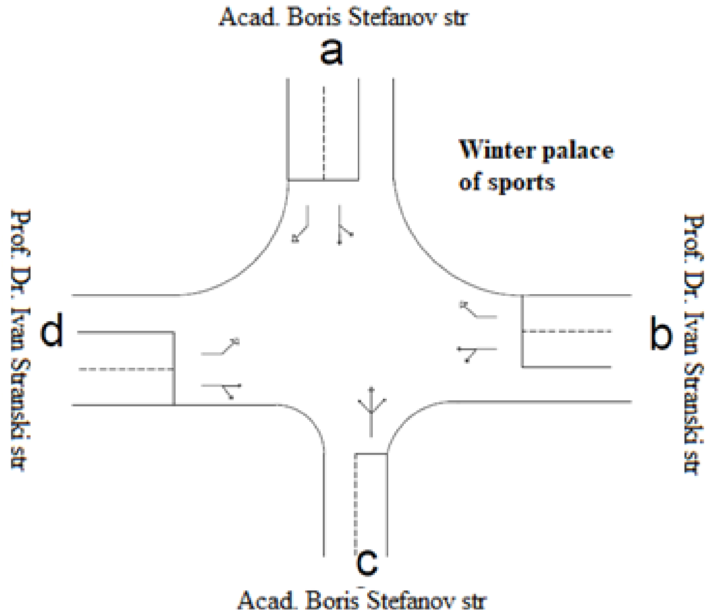

Fig. 3. A scheme of the redistribution of the crossroads on “Acad. Boris Stefanov” and “Prof. Dr. Ivan Stranski” streets

The changed configuration of the intersection and the values for the intensity of the traffic flows give grounds for determining three phases of traffic passing, which aims at safe passing of the cars from the flows with higher intensity (Fig. 4).

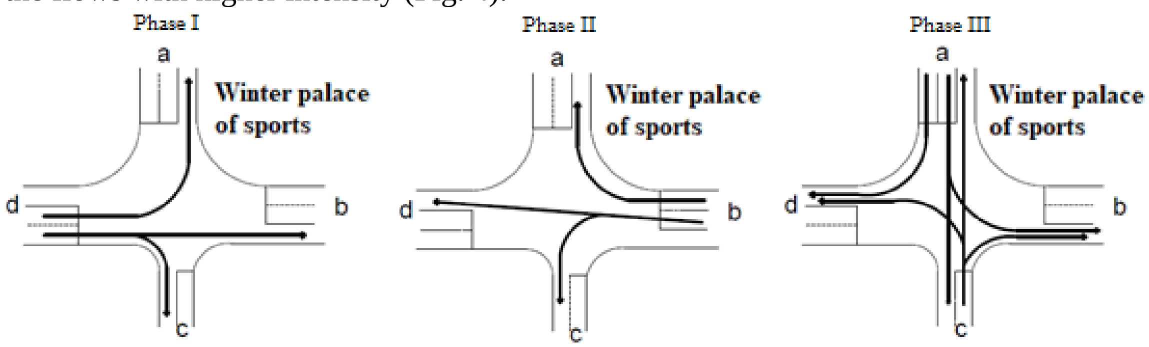

Fig. 4. Phase plan of the intersection of “Acad. Boris Stefanov” and “Prof. Dr. Ivan Stranski” streets

A diagram of the conflict zones in the defined phase plan is shown in Fig. 5. The duration of the intergreen time shall be determined for each of them. Table 2 is the matrix of intergreen times.

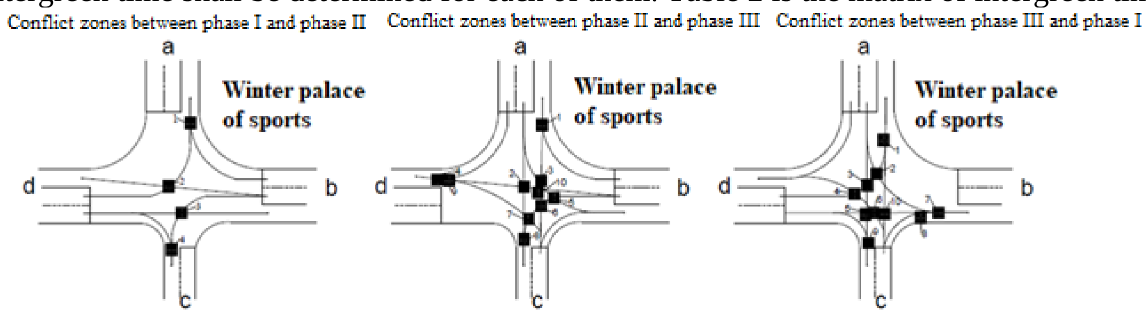

Fig. 5. A scheme of the conflict zones according to the proposed phase plan

Table 2.

Intergreen time matrix

Traffic flows			Entering traffic flows											
			Phase I			Phase II			Phase III					
			d - a	d - b	d - c	b - c	b - d	b - a	a - d	a - c	a - b	c - b	c - a	c - d
Clearing traffic flows	Phase I	d - a	X				2,95	**4,49**						
		d - b		X		1								
		d - c			X	4								
	Phase II	b - a				X							**4,33**	
		b - d					X		2,9	2,09	1,47		1,82	1,9
		b - c						X		3,10	1,61		4,30	3,7
	Phase III	a - d							X					
		a - c	2,64	2,74	**7,41**					X				
		a - b	3,00	3,73							X			
		c - b		1,32								X		
		c - a	1,63	1,70									X	
		c - d	3,45											X

The intergreen time adjacent to the respective phase is the largest of the calculated values for the respective conflict zones. It needs to be an integer in seconds. Guaranteeing the obtained values requires rounding to the larger integer. The adjacent intergreen times to the respective phases are as follows:

For Phase I – 5 s;
For Phase II – 5 s;
For Phase III – 8 s.

The traffic capacity for each phase (If_p) is determined according to the calculated intergreen times, taking into account the dependences of starting the queue at a green signal (Δt_{bc}), the time required for a car pass through the intersection (t_{pc}), the number of entrants cars at the intersection (A_e) and number of the lanes to pass traffic flows in each of the phases (l_t). This is need to be done for traffic flows that are passed only through the respective phase. For phase I these are flows 10, 11 and 12, for phase II these are flows 4, 5 and 6 and for phase III these are flows 1, 2, 3, 7, 8 and 9. The results of the calculations are shown in Table 3.

Table 3.

Results of calculation for traffic capacity of each phase

	t_{pc}, s	Δt_{bc}, s	A_e	t_p, s	If_{pl}, veh/s	l_t	If_p, veh/s
Phase I	5	1	5	10	0,5	2	1
Phase II	5	1	5	10	0,5	2	1
Phase III	8	1	8	16	0,5	2	1

The time required for a green signal for each of the phases (t_{ng}) is determined by a formula that takes into account the relationship between the arrival intensity of traffic flows (those wishing to cross the junction), the crossing intensity (traffic capacity) and the time of day for which perform the calculations. The intensity of arrival streams for each phase is defined as the sum of the intensity of each of the flows that are passed in one phase. For the junction in question, the required time for a green signal is determined for each of the three periods of the day. The required data and the obtained results are shown in Table 4.

Table 4.

Required data and the obtained results for needed green time for each phase

Period of the day	Phases									$\sum_{i=1}^{n} t_{ng}^{fi}$ сек
	Phase I			Phase II			Phase III			
	I_a	I_p	t_{ng}	I_a	I_p	t_{ng}	I_a	I_p	t_{ng}	
07:00 -13:00	0,204	1	4406	0,114	1	2462	0,105	1	2268	9137
13:00 - 18:00	0,189	1	3402	0,123	1	2214	0,150	1	2700	8316
18:00 - 22:00	0,239	1	3442	0,154	1	2218	0,171	1	2462	8122

The methodology for determining the cycle length requires the determination of the sum of the intergreen times for each of the periods of the day for which the calculations are performed. For each of the different periods of the day, the values are as follows:

From 7 to 13 – 12 463 s;
From 13 to 18 – 9 684 s;
From 18 to 22 – 6 278 s.

The obtained values allow to determine the number of cycles during the period for which the calculations are performed. The values are as follows:

From 7 to 13 – 692 cycles;
From 13 to 18 – 538 cycles;
From 18 to 22 – 349 cycles.

The presented results determine the duration of the traffic light cycle for each of the three periods. The duration of the green signal for each of the phases is calculated according to the obtained values for the cycle time according to the ratios of the road capacity and the intensity of the traffic flows.

The determination of final cycle times and green signal times complies with the mandatory application of integer durations in seconds and compliance with the restrictive conditions for a minimum phase duration of 8 seconds, which is regulated by the legislation of the Republic of Bulgaria (Ministry of Regional Development and Public Works, Ordinance № 17, 2015). The determined values for the cycle duration, the green signal times and the duration of the individual phases for each of the considered periods of the day are presented in Table 5.

Table 5.

Determined cycle lengths and phases duration for each period of the day

Times, s	Period of the day, h		
	07:00 - 13:00	13:00 - 18:00	18:00-22:00
t_c	33	33	37
t_g for Phase I	7	6	8
t_g for Phase II	4	4	5
t_g for Phase III	4	5	6

The mode of the light signal regulation for the separate periods of the day is graphically depicted with corresponding time-space diagrams in Fig. 6, Fig. 7 and Fig. 8

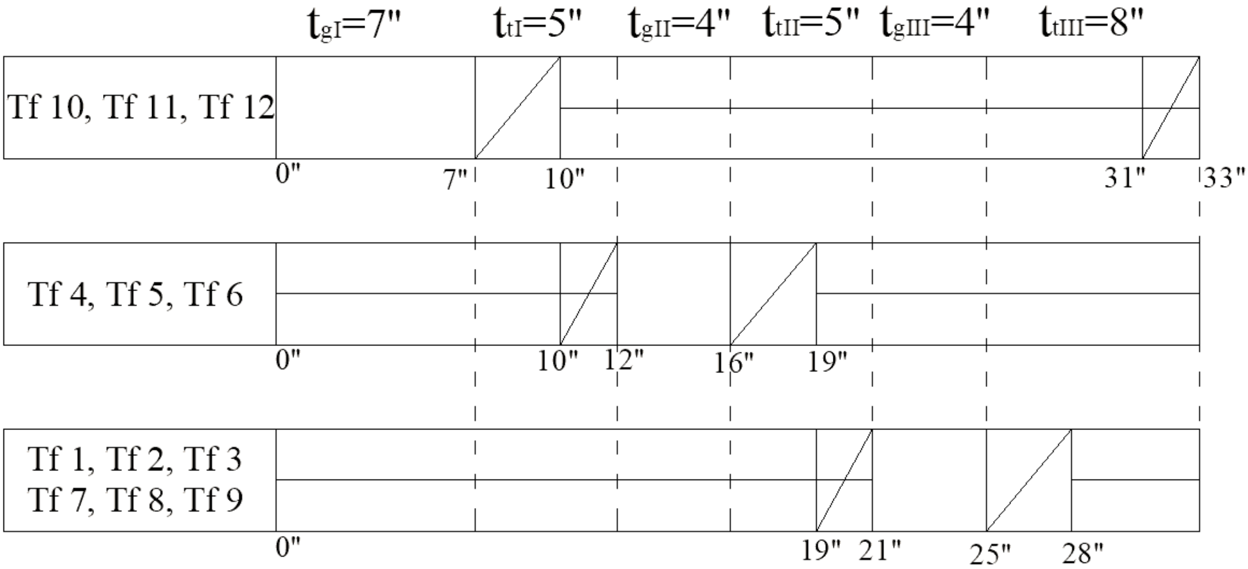

Fig. 6. Time-space diagram for period of the day from 07:00 to 13:00

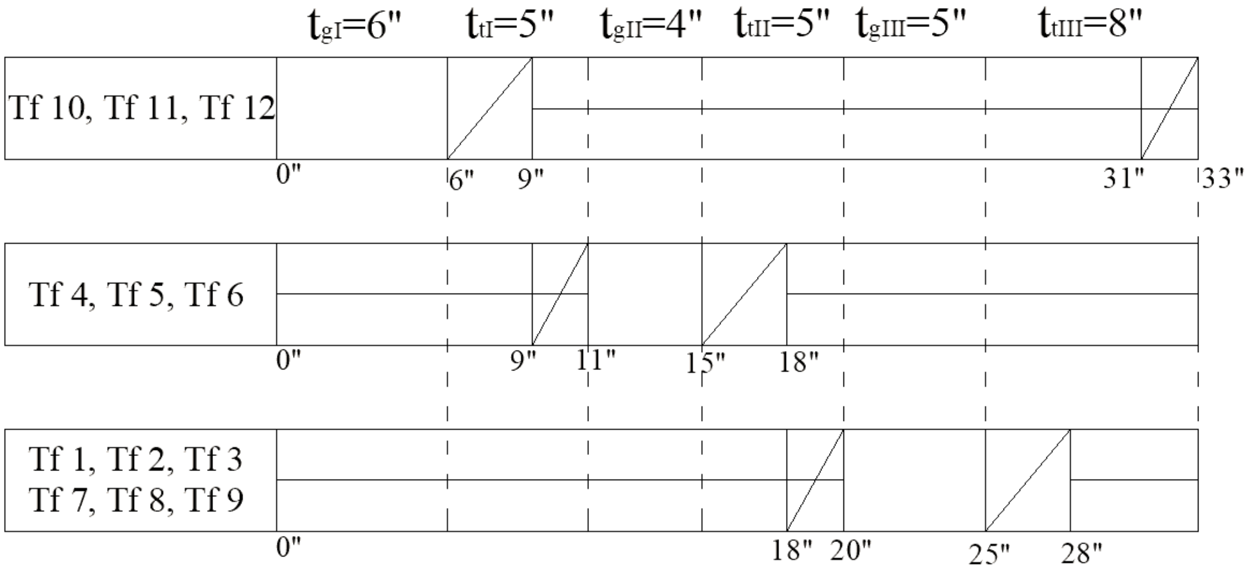

Fig. 7. Time-space diagram for period of the day from 13:00 to18:00

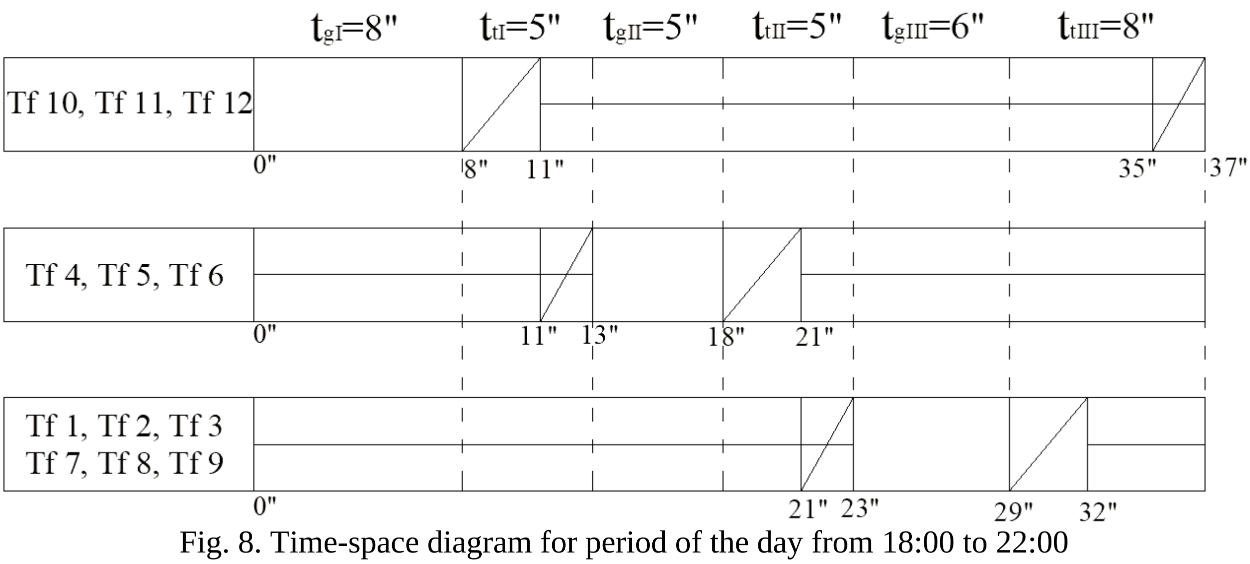

Fig. 8. Time-space diagram for period of the day from 18:00 to 22:00

If necessary, the modes of light signal regulation can be optimized subsequently taking into account the stochastic nature of the parameters of the transport flows and any needs that may arise to facilitate the passage of vehicles from urban public transport. The lack of such circumstances is consistent with the proposed plan of phases and green times of phases, but various studies show that the emergence of such needs is possible (Lin L., etc., 2016).

CONCLUSION

Passing through the four-approach intersection, between the streets "Acad. Boris Stefanov" and "Prof. Dr. Ivan Stranski" in the city of Sofia, is difficult during the peak hours of the day, which is a prerequisite for the formation of traffic accidents, violation of the schedule of public transport and fatigue of drivers.

The intersection is regulated by road signs, as the approach with the highest intensity should to waits for the vehicles from the other approaches to pass and queues are formed in it interfere with its normal functioning.

The configuration of the intersection gives grounds to change the distribution of road lanes on the approaches in order to optimize the passage of traffic flows through the intersection.

In view of the study, it has been shown that the use of traffic lights for the intersection in question is appropriate in terms of the intensity of traffic flows.

Three periods of the day have been determined, in which the passing of the traffic with different duration of the traffic light cycle can be organized. The first period is from 7 to 13 hours, the second period is from 13 to 18 hours and the last is from 18 to 22 hours.

The configuration of the intersection and the values for the intensity of the traffic flows give grounds for determining three phases, which aims at safe passage of cars from the flows with higher intensity.

The proposal to use light signal regulation at the intersection in question is expected to bring benefits of various kinds such as reduction of queue lengths during peak periods of the day, waiting time at the intersection, travel time of the population in this section, fuel consumption and the emitted harmful emissions.

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