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Developing Ways to Improve Traffic Management on Gayi Avenue

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ABSTRACT

The article considers the ways of road traffic improvement through the coordinated management system on Gayi Avenue. The system has been designed to reduce traffic delays, which could entail to positive results, suh as optimal speed, increased safety, reduced environmental pollution, traffic jam reduction, etc. As a result of the current research it has become obvious that there is an urgent need to implement an automated traffic control system in order to organize safe traffic in the main streets of Yerevan.

Introduction

Traffic management is a set of organizational and engineering measures that are implemented in the existing road network, ensuring the safety of vehicles, pedestrians, as well as the necessary speed. As already mentioned, nowadays it is necessary to implement an automated traffic control system (ATCS) in the main streets of Yerevan, which includes coordinated traffic management (Khilazhev and Sokolovsky, 2003). Consistent operation of a number of traffic lights is called coordinated system, which is aimed at the reduction of traffic delays. The principle of coordinated managemet consists of the process where the green signal at the next crossroad is switched on with a certain shift as compared to the previous crossroad, the duration of which depends on the passing time of vehicles across these crossroads. Thus, vehicles seem to move according to a schedule, approaching the next intersection at the moment when the green signal is turned on in the mentioned direction. After implementation of the system, the number of road accidents will be reduced by 10 %-15 %, and the traffic delays - by 15 %-20 % (Kremenets, 2005).

Materials and methods

Gayi avenue is one of the main streets of Yerevan. It has an overloaded traffic and is provided with intensive transport means which cause traffic delays, congestions, road traffic accidents, since the current methods of traffic organization fail to provide the needed results. The considered avenue is of 2300 m length and intersects the streets of D. Malyan, Moldovakan, Totovents, Safaryan, Hovhannisyan and Gyulikevkhyan. There are three or four lanes towards each traffic direction in Gayi avenue. The maximum distance between successive intersections is 532 meters. Such conditions enable to introduce one of the elements (coordinated management) from the automated management system in the traffic organization process.

Table 1. Traffic speed of vehicles in the highway street*

Speed of vehicles per ranges (km / h)	Average speed value within the ranges (km / h)	The number of vehicles	Distribution per frequency %	Accumulation of frequency in ascending order %
20-30	25	8	4	4
30-40	35	24	12	16
40-50	45	88	44	60
50-60	55	64	32	92
60-70	65	12	6	98
70-80	75	4	2	100
Total		200	100	

Table 2. The highway sizes*

Crossroads	Crossroad width (m)	District length (m)	Roadway width (m)	Number of traffic zones in one coordinated direction
1. Gayi av. – D. Malyan st.	28	0	16.3	3 (4)
2. Gayi av. – Moldovakan st.	70	495	21.20	3 (4)
3. Gayi av. – Totovents st.	36	230	23.90	3 (4)
4. Gayi av. – Safaryan st.	35	290	29.30	3 (4)
5. Gayi av. – Hovhannisyan st.	34	420	23.60	3 (4)
6. Gayi av. – Gyulikevkhyan st.	81	532	26.85	3

Table 3. The maximum intensity of traffic flows per directions on working days*

Directions / Number	I			II			III			IV		
	straight	right	left	straight	right	left	straight	right	left	straight	right	left
1	-	-	-	-	320	-	2405	121	-	602	-	329
2	1996	132	91	86	404	189	2014	101	118	24	59	304
3	1790	118	83	117	167	144	2094	132	243	102	58	192
4	1610	431	-	-	143	304	1918	178	244	-	203	360
5	1468	30	76	104	281	25	1737	158	31	46	55	137
6	1410	43	148	34	149	45	1664	110	161	45	133	72

*Composed by the author.

This system is based on three terms, two of which are already provided: more than two traffic lanes and less than 800 m distance should be ensured between the adjacent crossroads; the third term which is related to the availability of the similar adjustment cycle in the crossroads will be provided through the further calculations.

The baseline data needed for the contribution of coordinated management system to the Gayi avenue are introduced in Tables 1, 2, 3 and in Figure 1 (Rusevskiy, 2015).

Based on the data of Table 1, the histogram of vehicle speeds and a distribution curve per ranges are designed (Figure 2). The accumulation curve is designed in ascending order by adding the frequency percents in the 5th column of Table 1, which enables to determine the estimated speed of coordinated control with reliability per any percent (Figure 3).

The horizontal axis shows the speed of cars, while the vertical axis shows the frequency accumulation in ascending order. Typical points for the accumulation curve are the levels corresponding to 15 % (minimum allowable speed), 50 % (average speed value of the vehicles) and 85 % (maximum allowable speed) reliability. The speed value obtained via the mentioned method is surely to be rounded to the nearest ten unit. Thus, 50 km/h is selected as the calculated speed for coordinated control.

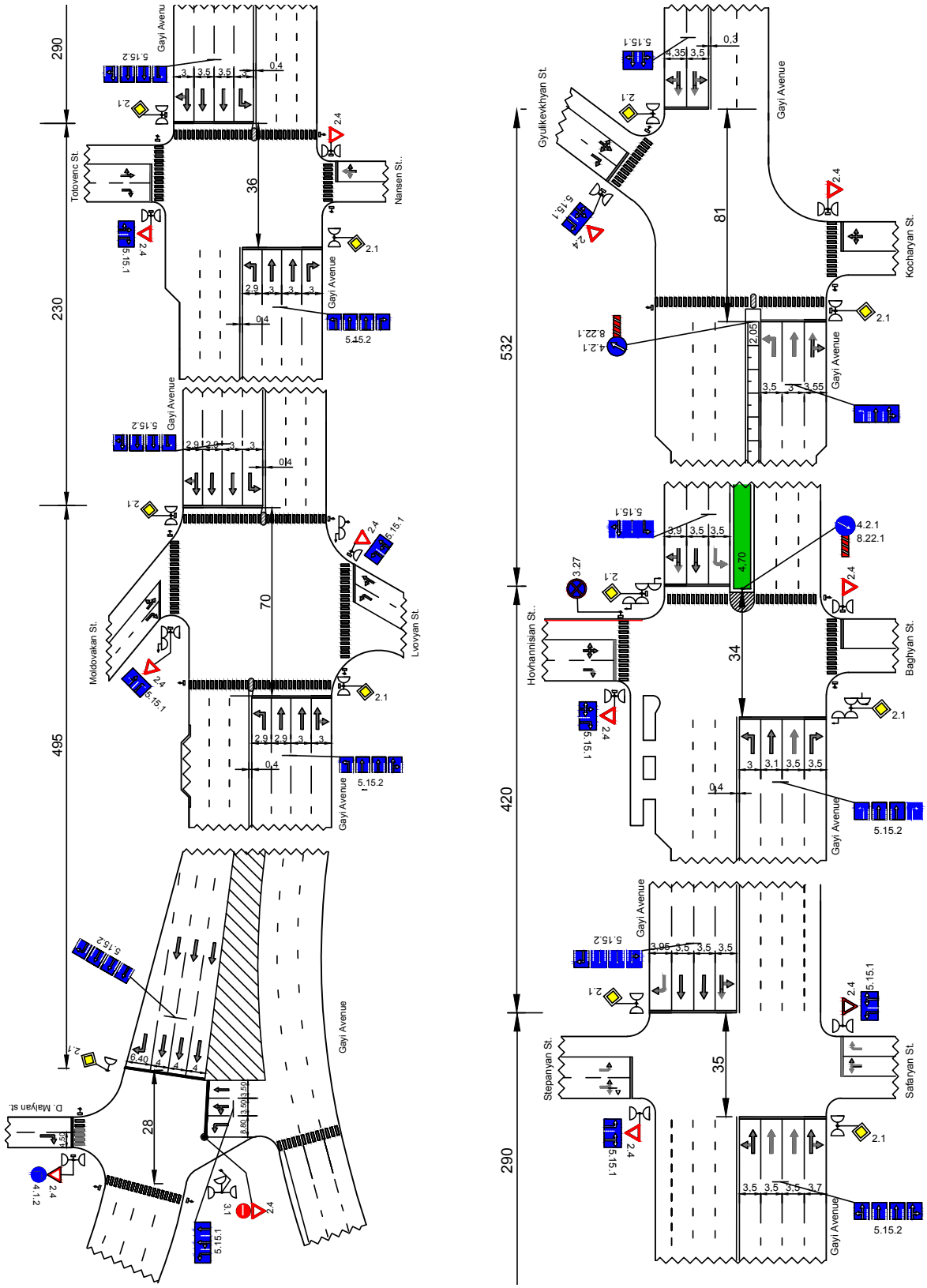

Figure 1. Diagram of Gayi Avenue (*composed by the author based on GOST 23457-86, 2013*).

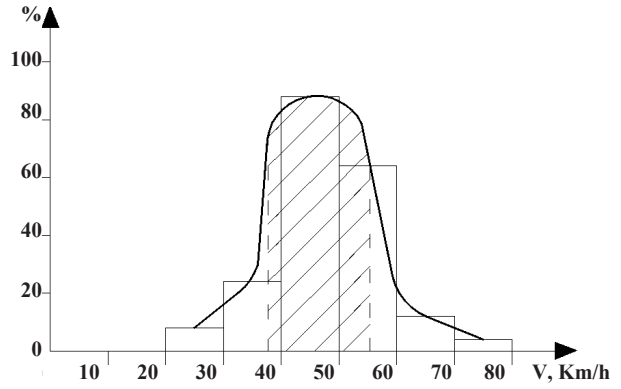

Figure 2. Vehicle speed histogram (*composed by the author*).

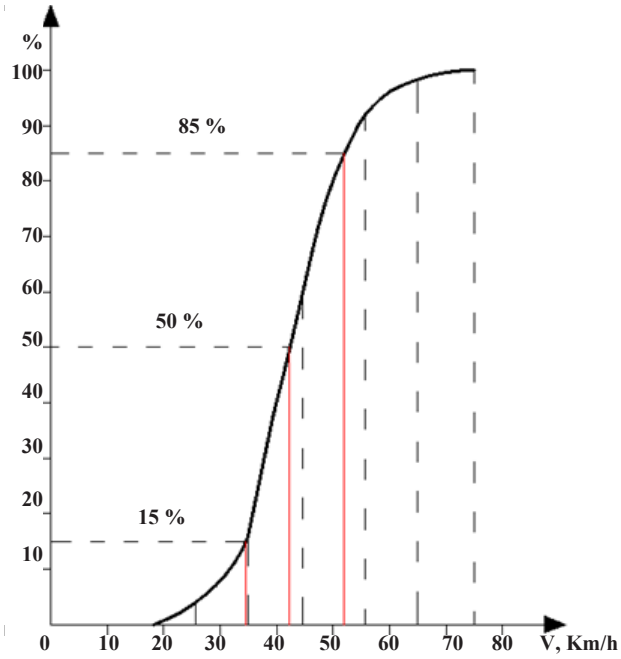

Figure 3. Vehicle accumulation curve (*composed by the author*).

Results and discussions

Now let's consider the intersections of Gayi avenue individually.

1. Gayi av. - D. Malyan st. crossroad: two-stage traffic organization is implemented at the mentioned crossroad. According to the data available in Table 4, the intensity of the busiest zone in the first stage will be (Rushevskiy, 2015):

$$N_1 = (N_{straight} + N_{right} + N_{left})/K_{mz} = (2405+121+0)/3.5 = 721 \text{ m/h},$$

where $N_{straight}$, N_{right} and N_{left} are the maximum intensities of straight , right and left traffic flows respectively, K_{mz} – multi-lane road coefficient: in case of the 1st road zone it is equal to 1, for the 2nd road zone - 1.9, for the 3d and 4th zones - 2.7 and 3.5 respectively. The intensity of the busiest zone (N_2) in the second stage will be:

$$N_2 = (N_{straight} + N_{right} + N_{left})/K_{mz.} = (602+0+329)/2.7 = 345 \text{ m/h}.$$

According to the approximate formula, the duration of the rigid adjustment cycle for traffic lights at the intersection of Gayi Avenue - D. Malyan street will be:

$$T_c = (N_1 + N_2)/14 = (721 + 345)/14 = 76 \text{ s}.$$

2. Gayi av.- Moldovakan st. crossroad: directional traffic organization is implemented at the mentioned intersection. The intensity of the busiest zone of the first stage (N_1) will be:

$$N_1 = (2014+ 101+ 118)/3.5 = 638 \text{ m/h}.$$

The intensity of the busiest zone of the second stage (N_2) will be:

$$N_2 = (86+ 404+ 189)/1.9 = 357 \text{ m/h}.$$

The duration of the rigid adjustment cycle for the traffic light in the given intersection will be:

$$T_c = (638 + 357)/14 = 71 \text{ s}.$$

3. Gayi av.- Totovents st. crossroad: the intensity of the busiest zone of the first stage (N_1) will be:

$$N_1 = (2094+ 132+ 243)/3.5 = 705 \text{ m/h}.$$

The busiest zone of the second stage (N2) will be equal to:

$$N_2 = (117+ 167+ 144)/1.9 = 225 \text{ m/h}.$$

The duration of the rigid traffic light adjustment cycle will be:

$$T_c = (705+ 225)/14 = 66 \text{ s}.$$

4. *Gayi av.– Safaryan st. crossroad*: for this intersection the traffic intensity of the busiest zone in the first stage (N_1) will be:

$$N_1 = (1918+ 178+ 244)/3.5 = 668 \text{ m/h}.$$

For the second stage (N_2) it will be equal to:

$$N_2 = (0+ 203+ 360)/1.9 = 296 \text{ m/h.}$$

The duration of the rigid traffic light adjustment cycle for the mentioned intersection will be:

$$T_c = (668+ 296)/14 = 68 \text{ s.}$$

5. Gayi av. – Hovhannisyan st. crossroad: the intensity of the busiest zone for the first stage (N_1) will be:

$$N_1 = (1737+ 158+ 31)/3.5 = 550 \text{ m/h.}$$

The intensity of the busiest zone in the second stage (N_2) will be equal to:

$$N_2 = (104+ 281+ 25)/1.9 = 215 \text{ m/h.}$$

The duration of the rigid traffic light adjustment cycle will be:

$$T_c = (550+ 215)/14 = 55 \text{ s.}$$

6. Gayi av. – Gyulikevkhyan st. crossroad: the intensity of the busiest zone of the first stage (N_1) will be:

$$N_1 = (1664+ 110+ 161)/2.7 = 716 \text{ m/h.}$$

The intensity of the busiest zone for the second stage (N_2) will be equal to:

$$N_2 = (45+ 133+ 72)/1.9 = 131 \text{ m/h.}$$

The duration of the rigid traffic light adjustment cycle will be:

$$T_c = (716+ 131)/14 = 61 \text{ s.}$$

After calculating the cycles, the duration of the intersection adjustment cycle that has the highest value is selected as the estimated one. The intersection of Gayi av.-D. Malyan st. ($T_c = 76$ s) is considered to be the "nodal/main crossroad". The adjustment cycle duration of the "nodal crossroad" is extended to all intersections, providing the second term for the introduction of coordinated control system (Klinkovstein, 2001). Then the duration of the green signal at each intersection is calculated using the following formula:

$$t_{gr} = t_0 – q + (N*T_c / 3600) * \text{q,}$$

where t_0 is the driver's reaction time (for calculations $t_0 = 2$ seconds), q is the minimum safe time span between vehicles (for mixed traffic $q = 3$ seconds), N is the intensity of the heaviest zone, T_c is the value of the "nodal crossroad" cycle. After calculating the main strokes (timing period), it is necessary to implement checking:

$$T_{c.} - t_{gr1} – t_{int/s} – t_{gr2} – t_{int/s} = 0 \text{ sec.}$$

If this condition is not met, the extended period is added to the main strokes in percent. The coordinated direction is provided with 50 %-70 %, in case of three stage adjustment - with 50 %, and the other two stages - with 2 5 %. The duration of intermediate stroke at the intersection of Gayi Avenue is 4 seconds.

• At the crossroad of Gayi av.- D. Malyan st. the duration of the green signal will be:

$$t_{gr1} = t_0 – q + (N*Tg / 3600) * q =$$
$$= 2 – 3 + (721 * 76 / 3600) * 3 = 47 \text{ sec.}$$

$$t_{gr2} = 2 – 3 + (345 * 76 / 3600) * 3 = 21 \text{ sec.}$$

$$76- 47- 4- 21- 4 = 0 \text{ sec.}$$

• At the crossroad of Gayi av.- Moldovakan st. the duration of the green signal will be:

$$t_{gr1} = t_0 – q + (N*Tg / 3600) * q =$$
$$= 2 – 3 + (638* 76 / 3600) * 3 = 39 \text{ sec.}$$

$$t_{gr2} = 2 – 3 + (357 * 76 / 3600) * 3 = 22 \text{ sec.}$$

$$76- 39- 4- 22- 4 = 7 \text{ sec.}$$

This condition is not met:

$$t_{gr1} + 7*70 \% = 39+5 = 44 \text{ sec.}$$

$$t_{gr2} + 7*30 \% = 22+2 = 24 \text{ sec.}$$

$$76- 44- 4- 24- 4 = 0 \text{ sec.}$$

• At the crossroad of Gayi av.- Totovents st. the duration of the green signal will be:

$$t_{gr1} = t_0 – q + (N*Tg / 3600) * q =$$
$$= 2 – 3 + (705* 76 / 3600) * 3 = 44 \text{ sec.}$$

$$t_{gr2} = 2 – 3 + (225 * 76 / 3600) * 3 = 13 \text{ sec.}$$

$$76- 44- 4- 13- 4 = 11 \text{ sec.}$$

The condition is not met:

$$t_{gr1} + 11*70 \% = 44+8 = 52 \text{ sec.}$$

t_{gr2} + 11*30 %= 13+3 = 16 sec.

76-52-4-16-4 = 0 sec.

• At the crossroad of Gayi av.– Safaryan st. the duration of the green signal will be:

$t_{gr1} = t_0 – q + (N*Tg / 3600) * q =$
$= 2 – 3 + (668* 76 / 3600) * 3 = 41$ sec.

$t_{gr2} = 2 – 3 + (296 * 76 / 3600) * 3 = 18$ sec.

76- 41- 4- 18- 4 = 9 sec.

The condition is not met:

t_{gr1} + 9*70 % = 41+6 =47 sec.

t_{gr2} + 9*30 %= 18+3 = 21 sec.

76-47-4-21-4 = 0 sec.

• At the crossroad of Gayi av. – Hovhannisyan st. the duration of the green signal will be:

$t_{gr1} = t_0 – q + (N*Tg / 3600) * q =$
$=2 – 3 + (550* 76 / 3600) * 3 = 34$ sec.

$t_{gr2} = 2 – 3 + (215 * 76 / 3600) * 3 = 13$ sec.

76- 34- 4- 13- 4 = 21 sec.

The condition is not met:

t_{gr1} + 21*70 % = 34+15 = 49 sec.

t_{gr2} + 21*30 %= 13+6 = 19 sec.

76-49-4-19-4 = 0 sec.

• At the crossroad of Gayi av. – Gyulikevkhyan st. the duration of the green signal will be:

$t_{gr1} = t_0 – q + (N*Tg / 3600) * q =$
$= 2 – 3 + (716* 76 / 3600) * 3 = 44$ sec.

$t_{gr2} = 2 – 3 + (131 * 76 / 3600) * 3 = 7$ sec.

76- 44- 4- 7- 4 = 17 sec.

The condition is not met:

t_{gr1} + 17*70 % = 44+12 =56 sec.

t_{gr2} + 17*30 %= 7+5 = 12 sec.

76-56-4-12-4 = 0 sec.

The coordinated management schedule is built in the following order (Novikov, 2009):

- Drawing the plan of the coordinated road keeping the vertical scale to the left of the vertical axis in the path-time coordinate system,
- Writing the design of adjustment cycle in front of each intersection,
- Drawing corresponding lines parallel to the horizontal axis over the borderline of each intersection,
- Setting up the adjustment cycle stages from left to right per scales along the borderlines drawn for the nodal crossroads,
- Drawing the time span (t_s) through the oblique lines (φ) from the start of the green signal towards the horizontal axis.

The tangent of the angle in oblique lines drawn towards the horizontal axis is proportional to the traffic speed:

$tg_\varphi = V_{est.} * M_h /3.6 * M_v = 50 * 0.5 /3.6 * 5.6 = 1.24,$

$\varphi = arctg\ 1.24= 51°,$

where $V_{est.}$ is the estimated traffic speed, M_h is the horizontal scale, M_v is the vertical scale.

The width of the time span is within the following limits:

$t_{gr} \geq t_s \geq 0.65\ t_{gr},$

where t_s is the maximum duration of the green signal at the nodal crossroad:

$t_s = 0.65 * 47 = 30.5$ sec.

In order to ensure unobstructed passage of vehicles in the direction of the coordinated road, the green signals of the traffic lights must have some shifts:

$t_{sh.} = 3.6 * L / V_{est.},$

where $V_{est.}$ is the estimated traffic speed, L is the length of the calculated space. Shifts are calculated from the main crossroads: thus, from the crossroad of Gayi av.- D. Malyan to that of Gayi av.- Moldovakan st.:

$t_{sh} = 3.6 * 495 / 50 = 36$ sec.

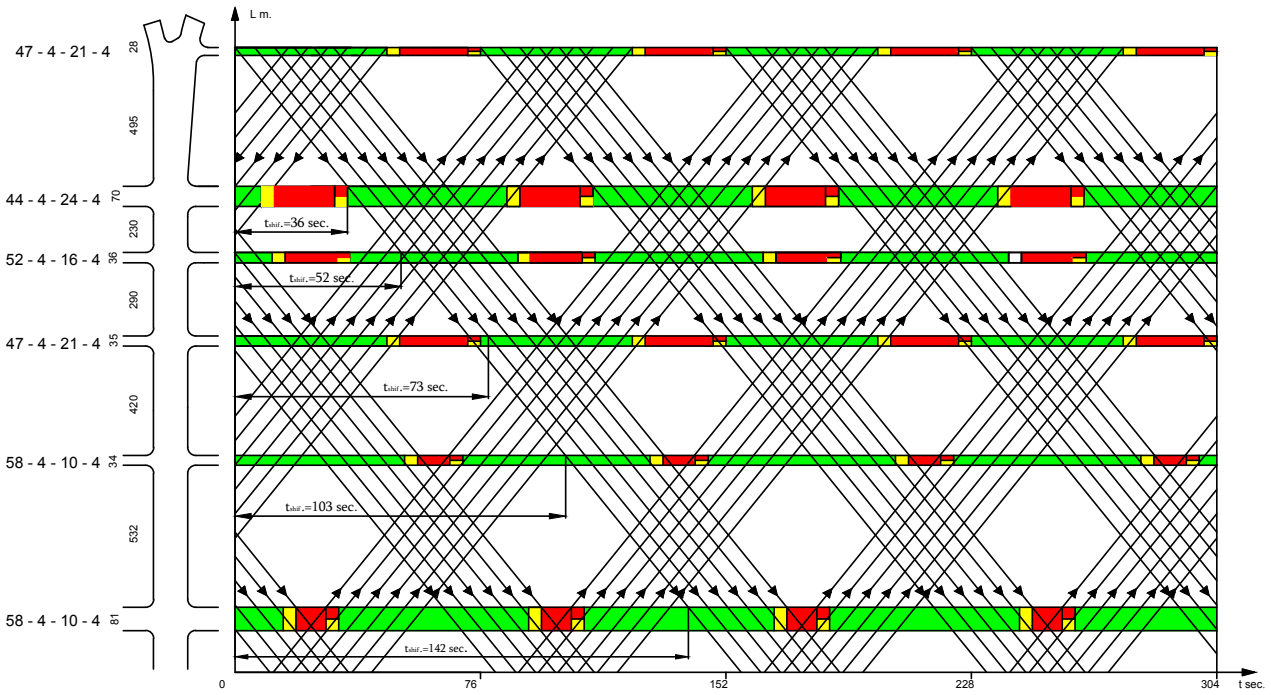

Figure 4. Coordinated management schedule (*composed by the author*).

From the crossroad of Gayi av.- D. Malyan to that of Gayi av.- Totovents st.:

$$t_{sh.} = 3.6 * 720 / 50 = 52 \text{ sec.}$$

From the crossroad of Gayi av.- D. Malyan to the Gai av.– Safaryan st. crossroad:

$$t_{sh.} = 3.6 * 1015 / 50 = 73 \text{ sec.}$$

From the crossroad of Gayi av.- D. Malyan to the Gayi av. – Hovhannisyan st. crossroad:

$$t_{sh.} = 3.6 * 1435 / 50 = 103 \text{ sec.}$$

From the crossroad of Gayi av.- D. Malyan to the Gayi av. – Gyulikevkhyan st. crossroad:

$$t_{sh.} = 3.6 * 1967 / 50 = 142 \text{ sec.}$$

The coordinated management schedule is presented in Figure 4 (Graphic-analytical method, 2013).

After designing the diagram, it becomes clear that the time span partially falls on the red signal at the crossroads of Gayi av. – Gyulikevkhyan st. and Gayi av. – Hovhannisyan st. There are 3 options for eliminating the mentioned problem: 1- reducing the time span, 2 - increasing the green signal duration and 3-reducing inclination in the time span angle. Since the time span has been calculated as equal to 0.65 t_{gr}, the problem can be solved by increasing the duration of the green signal in the conflict direction. After making the relevant changes, the structure of adjustment cycle at the mentioned intersections will be 58-4-10-4, 58-4-10-4 respectively.

Conclusion

Taking into account the abovementioned interpretations it can be stated that the introduction of the discussed coordinated management system in Gayi avenue will promote the increase of traffic safety, reduction of vehicle delays and traffic congestions, as well as the number of accidents, thereby somewhat improving traffic management. So, the approach of the transport means to the next intersection should occur at the moment, when the green signal is turned on in that specific direction.

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