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Prioritizing Vehicles that Carry Important Characters (Political) When Crossing Signalized Intersections

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ABSTRACT

In the urban transportation network as the traffic signals went green at the intersection of the upper hand, a group of vehicles move together and arrive at the next intersection, almost in group. If, at the same time as the group arrives, the signal of the corresponding route at this intersection is green, the total delay and stop of the vehicles will be significantly reduced and the intersection efficiency will increase significantly. The same strategy was implemented on the political vehicles in the study, so that the delay and stop time for them could be reduced. In this study, part of the political vehicle route from Saad-Abad Palace to the presidential office on Pasteur Street is considered. In this study, various strategies were developed to prioritize the vehicles in the Aimsun simulator software. Then, to detect the arrival of these vehicles to the intersection, two identifiers were embedded, one before the intersection and the other after it was installed. Among the results of this study are the following: There is an average increase in the average travel time for a scenario with an extra green time of 10 seconds and 15 seconds. The average delay time was 7 seconds for the additional green time scenario of 10 seconds and the average delay of 6 seconds for the sub-scenario of 15 seconds increased. The average number of stops per vehicle increased by 0.1 stops per vehicle in both cases.

Key words: Road intersection, Prioritization, Political Vehicle, Decreasing travel time.

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1. INTRODUCTION

The protection of characters is all that is required to preserve the characters in the face of possible threats, including assault, kidnap, assassination, etc. (1). The personality, namely, honor and majesty, and in the political sphere of characters, are the chosen people of a country or a nation who are responsible for administering the country in a given period, or in terms of social status, as the elite and national capital of a country. Moreover, in this respect, they must be protected. Precautionary measures to protect personalities include: precautionary measures in the area of movement, precautionary measures in public assemblies, precautionary measures and precautions at the workplace, precautionary measures and protection in the home (2). The most familiar means of controlling and regulating vehicle traffic and improving safety are traffic lights. Although traffic lights prevent a vehicle from moving in a different direction on the intersection, overall, if the correct timetable is calculated, the average vehicle delay will be less than that of the intersection without traffic lights (3). Typically, traffic lights are used independently to control intersections, but occasionally, in order of necessity and for better efficiency, it may be possible to interconnect cross-linking lights or all the intersections of a path in a way. And coordinated (4-6). Some types of lights are variable lights that are sensitive to traffic variations, and the green time range of each phase that has already been adjusted depends on the amount of traffic in the paths of that phase. Setting the green time of these lights is done by installing indicators at certain intervals from the stop line and in all directions to the intersection (7, 8). With regard to the security and safety of conservation studies, there are no prioritization studies in the area of public access protection. Therefore, this section examines the priority system for relief cars and buses in Iran and the world (9, 10). In a study, a smart system was designed to control urban traffic with priority of the bus. In such a system, the traffic lights are intelligent and the buses are equipped with intelligent systems. Time is the first priority of the factors. In this system, the link is defined as the road representative, which is defined by length, capacity, flow and number of passing cars, and intersections are defined with a set of links (11). The key factor is the intersection factor, which is responsible for planning the traffic lights, receiving and sending signals, and aims to provide a better time reservation for the bus factor (12, 13). The factor of the phase associated with the intersection factor is the optimum time for the green light to be used to evacuation the links. In general, using this method, bus priority (24% to 28% when traveling bus trips are saved) (14). In a study titled "Multi-functional system to control the traffic of personal and public transport vehicles", the purpose of traffic lights is to give priority to public and private vehicles. The direct method by keeping the bus agent at the station changes the factors in a short period of time and the indirect method changes the priority of the buses. In this system, multi-factor strategy improves traffic to private cars and buses, and 38% of buses and 51% of lost time improve all vehicles in traffic lights than fixed time (15). An investigation was conducted by Hong Chow and his colleagues at the California Department of Transportation with the aim of examining the use of different priority systems at intersections. For simulation based on satellite positioning systems, the time of sending the request in positions 15 seconds left to the intersection, 20 seconds, and 25 seconds and finally 30 seconds left to the intersection was considered, which ultimately, with no prioritization conditions. There are 8 different scenarios that are:

1. No Priority: No priority system
2. AVL (15): Make a priority request when the bus is 15 seconds away from the intersection.
3. AVL (20): Make a priority request when the bus is 20 seconds away from the intersection.
4. AVL (25): Make a priority request when the bus is 25 seconds away from the intersection.
5. AVL (30): Make a priority request when the bus is 30 seconds away from the intersection.
6. SVD (150): Insert the vehicle's detection device 150 meters before the intersection.
7. SVD (200): Insert the vehicle's detection 200 meters before the intersection.
8. SVD (250): Insert the vehicle's detection device 250 before above the intersection.

Among the various scenarios, the two scenarios AVL25 and SVD200 produced the best results to reduce delays in intersections. Clearly, the numbers that are expressed in the two above-mentioned scenarios are an average of delays; this is when the average vehicle delay time under non-priority conditions for each vehicle is about 135 seconds and the highest delay time for conditions with priority is 60 seconds; a number that is less than half the latency in no-priority mode. Also, in the studies on the Ringer intersection equipped with the TSP system, 57% decrease in intersection delays and 13.5% reduction in pedestrian delay at intersections and 35% reduction in travel time of the vehicle were achieved (16). In a study by Keitelson and his colleagues in Seattle, commissioned by the US National Consultative Commission and the US Transportation Research Commission, the results of the implementation of the priority system were examined on three intersections. In this research, the greening system was introduced earlier, which reduced 24% of stops for buses at these intersections, a 8% reduction in travel time, and a 24% reduction in vehicle delay time at intersections (17).

2. METHODOLOGY

In this study, a total of 11 statisticians and 3 observers were used, which monitored the task of surveying the problems and requests of statisticians. This was done so that nobody leaves the site due to problems and the statistics do not get bogged down. If necessary, these observers could replace any individual. Prioritization of the traffic light can be addressed at three different levels:

1) Limited Level: Includes a small area of the network and includes only a few intersections.
2- Route level: Includes a number of corridors in a route line.
3- Extensive coverage: Includes improved and widespread use of all network lines.

Some of the intersections due to the massive volume of vehicles, as well as the high mobility of public transport and its location in relation to other intersections, do not allow for timing and prioritization of all lines because of the subsequent rejection of the traffic flow in There will be adjacent intersections. Therefore, the use of each of these levels requires an examination of the network status and intersection features on the route. All three intersections in this study have 3-phase scheduling. Tracking at these intersections was done field-by-stage and the volumes were taken in 12 intersections phases for a conventional car. The results show that the peak hour of the three intersections is the peak of the evening, and the volume of this peak hour was used in simulation.

2.1. Different priority scenarios

The priority given in this study was expressed at the level of one, a limited level was performed and prioritization was considered in the phasing of both paths. To this end, three different priority scenarios were examined:

Scenario 1: Prioritize at all three intersections of the intended vehicle
Second scenario: Prioritization at two intersections of Mirza Shirazi and Shahid Motahari
Third scenario: Prioritizing at the central junction, Mirza Shirazi
The criteria for selecting the best scenario among the scenarios are, at the first step, the least delayed time for these cars and in the next step, the least delay time at each intersection.

2.2. Case study

The high traffic volumes in metropolitan cities create security barriers for carriers carrying political persons. Prioritizing these cars at signalized intersections is a solution that can be used to improve the quality of service and performance of the cars by reducing their travel time. In this study, part of the political vehicle route from Saad-Abad Palace to the presidential office on Pasteur Street is considered. These intersections are the intersection of Shahid Beheshti Street with Ghaem Farahani Street, intersection of Shahid Beheshti Street with Mirza Shirazi Avenue and the intersection of Valiasr Street with Shahid Motahari St. (Figure 1).

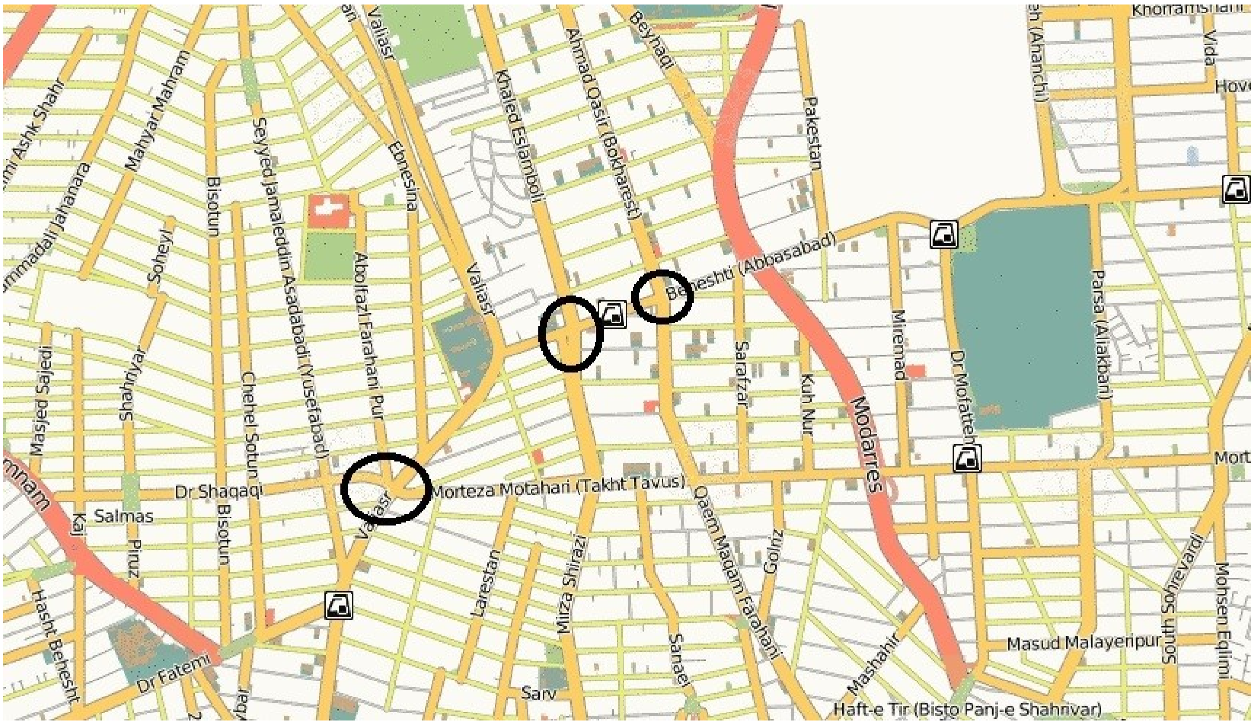

Figure 1. Case Study Area

Different scenarios for prioritizing the three intersections in the route are evaluated. Using the results of the simulation software, the best scenario is chosen. In the following, the studied area and the simulations are analyzed and their results analyzed. For this purpose, the volume of intersections is presented in Table 1, Table 2 and Table 3 and simulations are performed. Further analysis of the results and discussions is done on them in detail.

Table 1. The circulation traffic volume at the intersection of Shahid Beheshti and Qa'im Farahani

Intersection	*Approach*	*North*	*East*	*West*	*south*
Shahid Beheshti and Qa'im Farahani	North	-	-	112	225
	East	132	-	340	145
	West	-	-	-	-
	south	238	-	98	-

Table 2. The circulation traffic volume at the intersection of Shahid Beheshti and Mirza Shirazi

Intersection	*Approach*	*North*	*East*	*West*	*south*
Shahid Beheshti and Mirza Shirazi	North	-	-	102	241
	East	111	-	324	119
	West	-	-	-	-
	south	241	-	92	-

Table 3. The circulation traffic volume at the intersection of Valiasr-Shahid Motahhari

Intersection	*Approach*	*North*	*East*	*West*	*south*
Valiasr-Shahid Motahhari	North	-	126	145	268
	East	-	-	-	-
	West	-	259	-	167
	south	-	-	-	-

3. RESULTS AND DISCUSSION

In order to prioritization in the Aimsun simulator software, the vehicles were equipped and then to detect the arrival of these cars at the intersection, two detectors were installed, one before the intersection and the other after it, and the detector was set up to After 3 seconds, submit the request for priority passage. At these 3 intersections, traffic volumes were often used to reach the intersection of the vehicle, even if the lights were green, it took 3 seconds to leave the intersection. Simulations were performed for the status quo and three scenarios, and averaged over three times for each mode. In the Table 4, Table 5, Table 6 and Table 7, a summary of the simulation results is presented.

Table 4. Information on the status quo of the case study area

status quo			
Total delay (Sec / Km)	Delay to cars (Sec / Km)	Delay to the intended vehicles (Sec / Km)	Average overall length of the queue (Veh)
132.65	100.07	32.58	184.26

Table 5. Information on the first scenario in the case study area

First Scenario			
Total delay (Sec / Km)	Delay to cars (Sec / Km)	Delay to the intended vehicles (Sec / Km)	Average overall length of the queue (Veh)
169.36	136.07	18.08	205.64

Table 6. Information on the second scenario in the case study area

Second Scenario			
Total delay (Sec / Km)	Delay to cars (Sec / Km)	Delay to the intended vehicles (Sec / Km)	Average overall length of the queue (Veh)
161.47	129.54	21.61	203.58

Table 7. Information on the third scenario in the case study area

Fourth Scenario			
Total delay (Sec / Km)	Delay to cars (Sec / Km)	Delay to the intended vehicles (Sec / Km)	Average overall length of the queue (Veh)
154.91	106.22	29.67	191.25

According to Figure 2, delays are reported for different vehicles, which is expected to be higher than the expected overall delay of the vehicles and delays to the political vehicles. In Figure 3, the same is true, but the delay of the intended vehicles is very low and the delay of other vehicles is greatly increased, which according to the decision maker can choose or refuse this scenario.

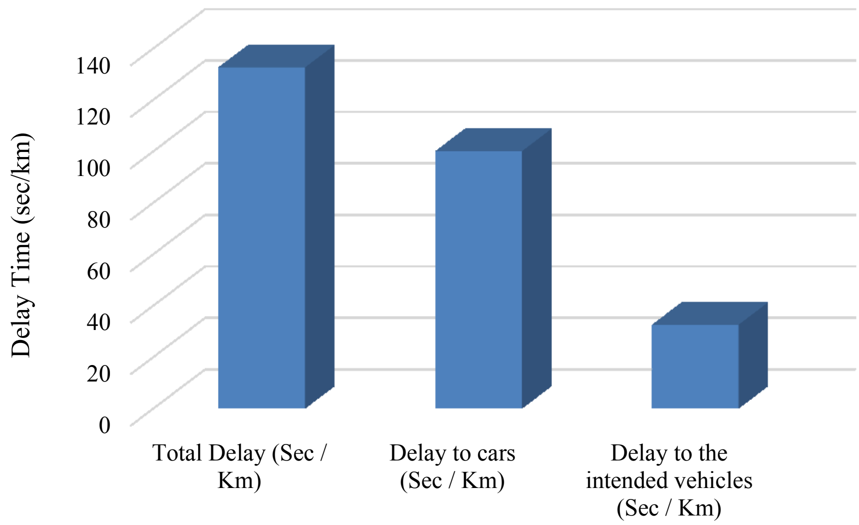

Figure 2. The amount of delays in the present situation of the studied area

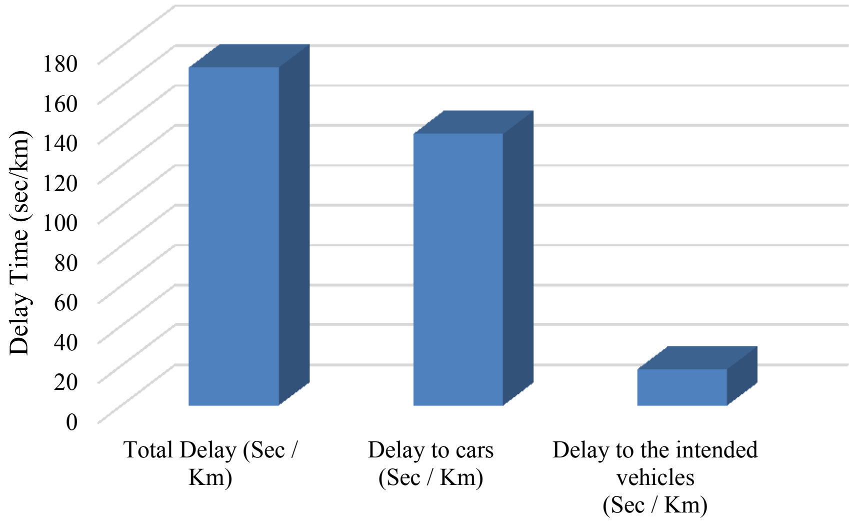

Figure 3. The amount of delays in the first scenario of the studied area

As shown in Figure 4, in the second scenario, the delay of the desired vehicles increases slightly compared to the first scenario, but the delay of other vehicles and overall delay is reduced, which according to the decision maker can be the desired option chose.

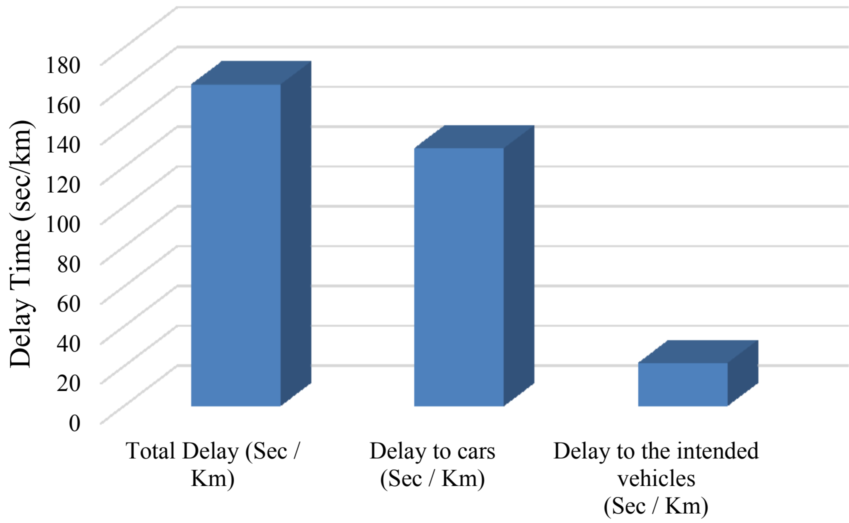

Figure 4. The amount of delays in the second scenario of the studied area

In Figure 5, it can be seen that the delay of the desired vehicles from the first and second scenarios is higher, but there is still a lower latency than the current situation.

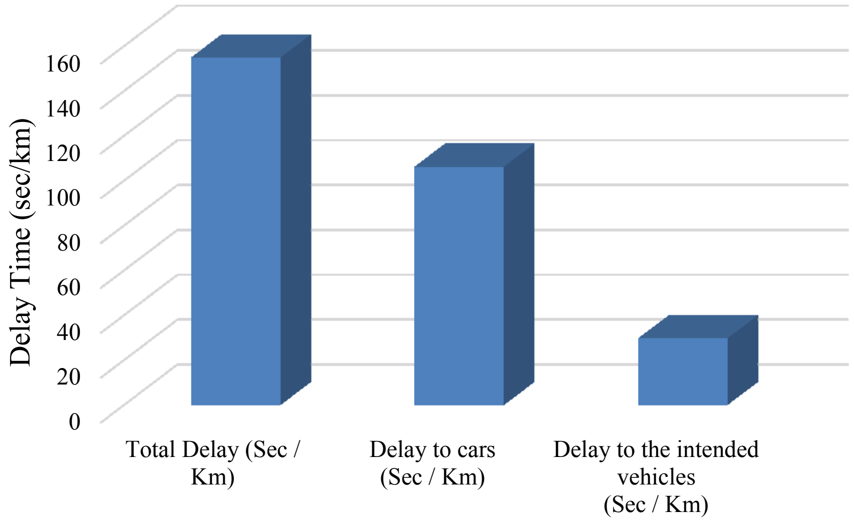

Figure 5. The amount of delays in the third scenario of the studied area

As can be seen in Figure 6, the first scenario has the highest overall delay, but according to Figure 7, the lowest delay time in vehicles is less than the current situation, and from this perspective scenarios are not useful.

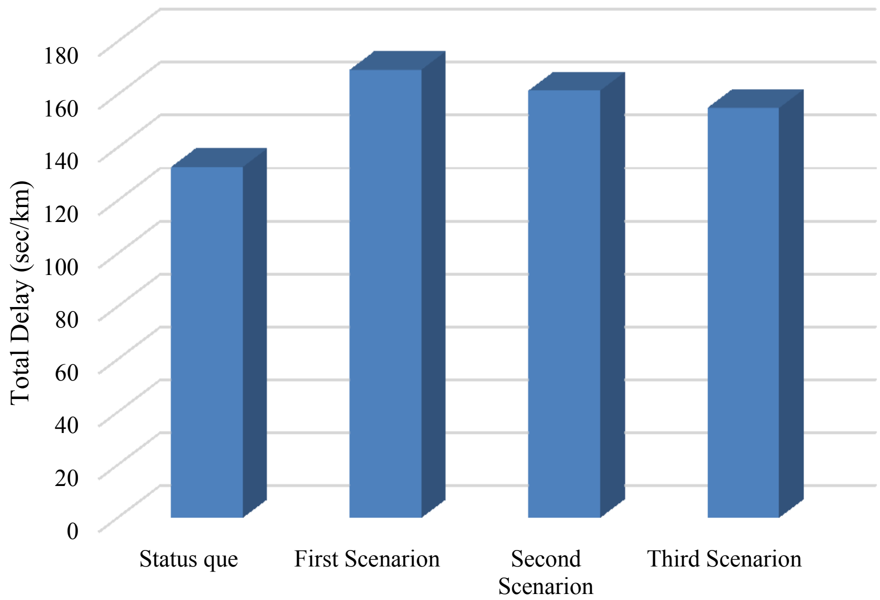

Figure 6. The overall delay for different scenarios

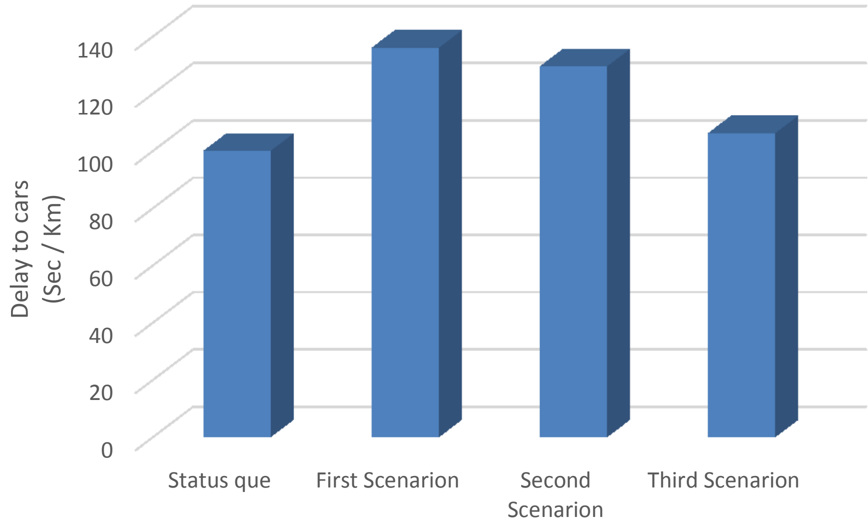

Figure 7. Delay time of vehicles in different scenarios

According to Figure 8, the delay time for the vehicles in the first scenario is lower than the rest, and this option can be the preferred one. However, as shown in Figure 9, the overall queue length in this scenario is high.

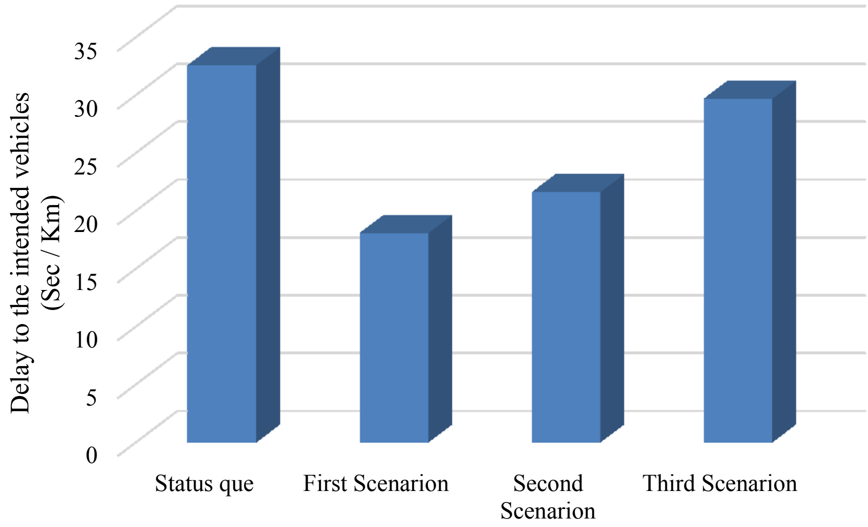

Figure 8. The amount of delays incurred for the political vehicles in different scenarios

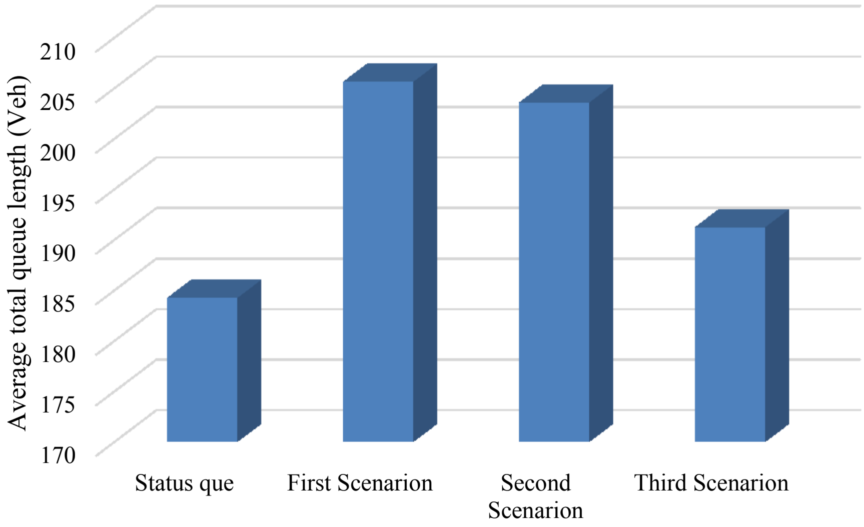

Figure 9. The queue length in different scenarios

Simulation in this section resulted in the following:

1. With the implementation of the Priority Guideline, the traffic lights for the vehicles in this study were significantly reduced in terms of delay time imposed on the system, so this scheme is an effective way to improve the service of these vehicles and reduce travel time.

2- The implementation of the priority design of these cars due to the upgrade of the system and the safety of these cars, is a low cost method than other methods.

3. In order to prioritize the traffic lights to these vehicles on each path, it is necessary to perform simulation according to the conditions of each simulator and to extract the appropriate design with high efficiency for each route.

3.1. Traffic Light synchronization

To investigate the two simple and inverse synchronization methods, Shahid Beheshti Street is simulated with two intersections of Qa'm-e-Magham and Mirza Shirazi. The traffic in this street is saturated during peak hours. For this reason, the reverse is used to coordinate its intersections. In non-peak hours, this street acts as a sub-saturation and simple synchronization (positive phase difference) is performed. The network was originally modeled in Synchro software (18), and the cycle length and intersection phases were optimized. The arterial delay time in the two modes of saturation and sub-saturation by Synchro software is presented in the table below (Table 8).

Table 8. Delay time of Shahid Beheshti Street in two modes of saturation and sub-saturation in the fourth scenario

Queue length (Veh)	*Delay Time (Sec/Km)*			
	Total delay (Sec / Km)	Delay to cars (Sec / Km)	Delay to the intended vehicles (Sec / Km)	Total Queue length (Veh)
Saturation	157.49	130.54	36.82	186.69
Sub Saturation	114.51	92.47	20.49	177.27

The cycle length and phasing obtained from Synchro are used in the next step in AIMSUN software. At this stage, by plotting different scenarios for two conditions of saturation and sub-saturation, different phases are tested. According to the delay criterion, the best phase difference is determined for the two conditions. The following table summarizes the results of this simulation (Table 9).

Table 9. Determination of the phase difference using the delay time criterion in the sub saturation and saturation conditions

Delay (Sec/Km)		*Phase difference (sub saturation)*	*Delay (Sec/Km)*		*Phase difference (saturation)*
Total	Average		Total	Average	
150.29	148.62	10	148.44	147.26	-5
145.12	142.95	15	143.57	142.81	-10
146.54	144.28	25	142.36	141.51	-15

As the results can be understood, by considering the minimum delay criterion, the phase difference of -15 is chosen as the best phase difference for saturation conditions. Under saturation conditions, Synchro software provides a 13 second phase difference as an optimal phase difference, which is achieved by simulating a network in AIMSUN, with a fuzzy difference of about 15 seconds as the best phase difference with the least delay criterion.

3.2. Calibration and validation of the variables studied

In this section, the existing calibration and validation of the variables are discussed. For this purpose, traffic volume of simulated and observed samples in the study area and their calibration data are presented in Table 10, Table 11, Table 12 and Table 13. In the simulation model, the detectors set the traffic volume at each intersection along the street. The number of simulated traffic was compared with the observed data. The two general variables, the simulation step (reaction time), and the reaction time at the stop were set in the AIMSUN model to indicate the most appropriate field measurements of traffic volume on the desired street. Coefficient of correlation, oil inequality coefficient (19) and root mean square error (RMSE) were selected as performance measures. Quantifies the mean root error of the simulator's overall error, penalizing a larger error at higher rates than small errors. The mean square root mean square error (RMSNE) quantifies the percentage of total error using the mean of observed data (20).

$$RMSE = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(Y_i^{sim} - Y_i^{obs})^{\wedge}2} \quad (1)$$

$$RMSNE = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(\frac{Y_i^{sim} - Y_i^{obs}}{\bar{Y}^{obs}})^{\wedge}2} \quad (2)$$

Where Y_i^{obs} and Y_i^{sim} are respectively observed and simulated measurements at the point-time point i. The U-value statistic also provides information about relative error.

$$= \frac{\sum_{i=1}^{N}((Y_i^{obs} - \bar{Y}^{obs}) * (Y_i^{sim} - \bar{Y}^{sim}))}{\sqrt{\sum_{i=1}^{N}((Y_i^{obs} - \bar{Y}^{obs})^{\wedge}2 * \sum_{i=1}^{N}(Y_i^{sim} - \bar{Y}^{sim})^{\wedge}2}} \quad (3)$$

$$U = \frac{\frac{1}{N}\sum_{i=1}^{N}(Y_i^{sim} - Y_i^{obs})}{\sqrt{\frac{1}{N}\sum_{i=1}^{N}(Y_i^{sim})^{\wedge}2} + \sqrt{\frac{1}{N}\sum_{i=1}^{N}(Y_i^{obs})^{\wedge}2}} \quad (4)$$

U is bounded, $0 \leq U \leq 1$ and U = 0 represents a perfect fit between the observed and simulated measurements. The fuel coefficient can also be divided into inequalities: the biasU^M, the varianceU^S, and the covarianceU^c, which are represented by the following equations:

$$U^M = \frac{(\bar{Y}^{sim} - \bar{Y}^{obs})^{\wedge}2}{\frac{1}{N}\sum_{i=1}^{N}(Y_i^{sim} - Y_i^{obs})^{\wedge}2} \quad (5)$$

$$U^S = \frac{(\sigma^{sim} - \sigma^{obs})^{\wedge}2}{\frac{1}{N}\sum_{i=1}^{N}(Y_i^{sim} - Y_i^{obs})^{\wedge}2} \quad (6)$$

$$U^c = \frac{2(1-\rho)\sigma^{sim} * \sigma^{obs}}{\frac{1}{N}\sum_{i=1}^{N}(Y_i^{sim} - Y_i^{obs})^{\wedge}2} \quad (7)$$

$$U^M + U^S + U^c = 1 \quad (8)$$

Where Y and S are the mean and standard deviations of the data series, r is their correlation coefficient. The bias reflects the systematic error, while the variance indicates how the simulation model illuminates how well the change in observed data is. Both should be as close to zero as possible and covariance should be close to zero.

Table 10. Calibration data capacity at AM peak hours

RMSNE %	*RMSE*	*Theils coefficient, U*	*Correlation, ρ*	
EB	EB	EB	EB	AM Peak
11.99	7.6308	0.0522	0.9837	7:15
7.35	6.5425	0.0340	0.9877	7:30
9.24	9.7266	0.0434	0.9831	7:45
7.05	8.8380	0.0328	0.9858	8:00
10.55	12.5099	0.0505	0.9571	8:15
10.31	11.7016	0.0473	0.9844	8:30
7.44	8.1474	0.0355	0.9912	8:45
12.89	13.8082	0.0635	0.9734	9:00
9.6	9.8632	0.0449	0.9811	Average
2.25	2.5629	0.0265	0.0114	STD DEV

Table 11. Calibration data capacity at PM peak hours

RMSNE %	*RMSE*	*Theils coefficient, U*	*Correlation, ρ*	
EB	EB	EB	EB	AM Peak
8.21	11.4079	0.0398	0.9665	4:15
7.51	11.3279	0.0374	0.9858	4:30
11.79	18.7055	0.0589	0.9704	4:45
8.10	13.3189	0.0385	0.9710	5:00
11.90	20.2415	0.0599	0.9894	5:15
9.31	16.0248	0.0453	0.9547	5:30
12.59	20.0144	0.0581	0.9651	5:45
16.20	23.7540	0.0742	0.9651	6:00
10.69	16.8495	0.0514	0.9710	Average
2.99	4.5655	0.0136	0.0116	STD DEV

Table 12. Calibration data capacity at AM peak hours (Theil coefficients)

Theils Covariance, U^c	Theils Variance, U^s	Theils bias, U^m	
EB	EB	EB	AM Peak
0.5735	0.0016	0.4395	7:15
0.8771	0.0445	0.0445	7:30
0.7325	0.1892	0.0927	7:45
0.8958	0.0311	0.0742	8:00
0.8791	0.0927	0.0270	8:15
0.5184	0.5066	0.410	8:30
0.4099	0.5695	0.0227	8:45
0.3752	0.1644	0.4560	9:00
0.6576	0.1999	0.1497	Average
0.2165	0.2192	0.1859	STD DEV

Table 13. Calibration data capacity at PM peak hours (Theil coefficients)

Theils Covariance, U^c	Theils Variance, U^s	Theils bias, U^m	
EB	EB	EB	AM Peak
0.9051	0.0809	0.0149	4:15
0.4238	0.0064	0.5839	4:30
0.3666	0.2705	0.3730	4:45
0.7275	0.0925	0.2121	5:00
0.1430	0.0704	0.7871	5:15
0.9099	0.0681	0.0143	5:30
0.3888	0.0984	0.5458	5:45
0.2179	0.2989	0.4819	6:00
0.5105	0.1231	0.3766	Average
0.2995	0.1041	0.2780	STD DEV

3.3. Average travel time Validation

The average travel time using a moving floating vehicle was collected for traffic westbound during peak periods of AM and PM. Then, the collected data is compared with the travel time of the simulation, as shown in Table 14. Traffic along the path of Shahid Beheshti Street in the simulation model takes 44 seconds less than the observation trip at the peak hour on the western route. At PM, traffic in the simulation model on the Western route was 25 seconds shorter than travel time. Since time travel was collected from field observations in minutes, the travel time difference between the simulator and observation data was +/- 1 minute accurate.

Table 14. Average travel time comparing

	Average Travel Time		
	Observed	Simulated	Difference
AM Peak	19:00	19:44	0:44
PM Peak	22:21	22:46	0:25

3.4. Travel time Validation of Political vehicles

Delay time of vehicles at intersections and traffic congestion make significant changes during their travels. The average travel time of these cars from GPS data is from field observations and traffic simulation taken in Table 15. The travel time of the intended vehicles is longer than the time it was extracted from the GPS data. In the western direction during peak hours of PM, the observed time was 43 seconds more than simulated time. The travel time of the AIMSUN simulator during the AM peak hours in the west was about 24 seconds longer than field observations.

Table 15. Average travel time comparing of the intended vehicles

	Average Travel Time		
	Observed	Simulated	Difference
AM Peak	19:35	18:52	0:43
PM Peak	21:21	22:45	0:24

As shown in Table 16, the average traffic volume in the peak hours of PM is significantly higher than the peak hours of the AM (increase of 50% and 110%).

Table 16. Average travel time comparing of the intended vehicles in AM and PM

Average traffic volume (Veh / Km)	
322	AM Peak
499	PM Peak

3.5. Analysis of modeling results

Traffic data from the simulation model was collected to compare the effectiveness values of the priority traffic light strategy. The system statistics in the AIMSUN User Guide are defined as follows. The total statistics of the simulated network are shown without using the priority light strategy in Figure 10 and Table 17. During the peak period (4-6 PM), traffic is much heavier than in the morning (7-9AM). There was a 40% increase in the flow of traffic at peak hours at PM. The average speed in the system is reduced by 9% from 19.8 to 18 MPH compared to the AM period. The average travel time, delay time and stopping time in each vehicle at noon rush hour increased by 21%, 31.7% and 25%, respectively.

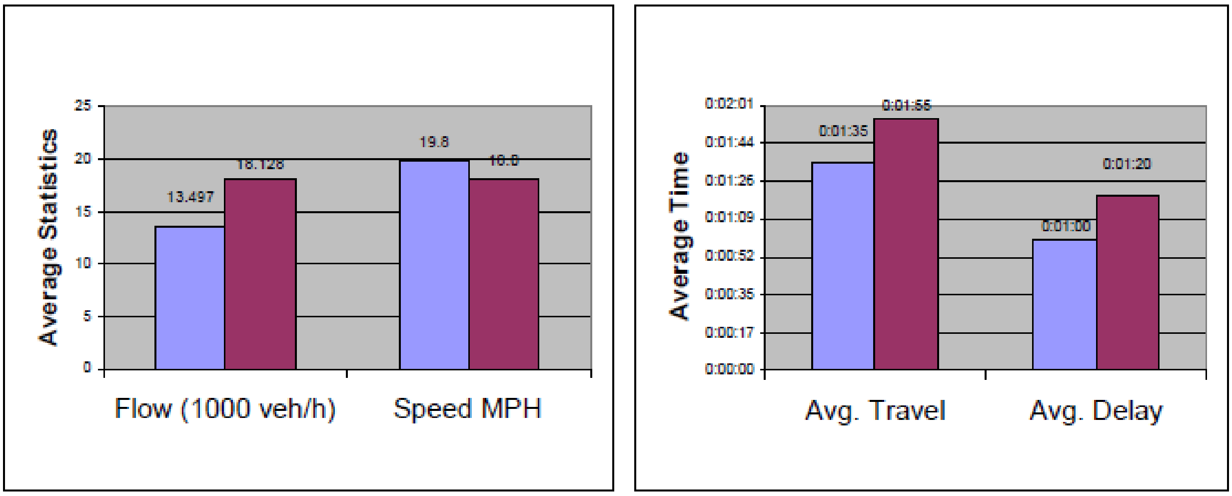

Figure 10. Travel time, network delay, speed and flow at peak hours in the morning and afternoon

Table 17. Network statistics at peak hours in the morning and afternoon

AM vs. PM Network Statistics - No Signal Priority Strategy				
Overall Network Statistics	Flow 1000 veh/h	Speed MPH	Avg. Travel Time hh:mm:ss	Avg. Delay Time hh:mm:ss
AM Peak	13.497	19.8	0:01:35	0:01:00
PM Peak	18.128	18.0	0:01:55	0:01:19
Average Change	4.631	-1.8	0:00:20	0:00:19
Average Change %	34.31%	-9.09%	21.05%	31.67%

3.6. Effect Measurement

The average speed of these vehicles, travel time and stop time during simulations were collected to measure effectiveness with a priority strategy without priority. These actions are defined as follows.

3.6.1. AM Peak

The statistics for the simulation with the priority traffic light strategy and without it are shown in Table 18 and Table 19 for peak hours of AM. The time and speed of travel are also depicted in Figure 11 and Figure 12. Two cases were studied in the AM peak period. The maximum additional green length of 15 seconds and 10 seconds was respectively studied for comparing the reduction of travel time and traffic delay. It took about 20 (19) minutes for an EB vehicle to travel on Shahid Beheshti Street without the priority of the lights. Using the traffic light priority strategy with an extra green limit of 10 seconds for the vehicle, the travel time for this vehicle decreased by 2 minutes in EB, or 10% in EB. The delay time is reduced by about 11% ~ 13%.

Table 18. PM Peak statistics

Priority Extension Time = 10 sec					
AM PEAK Statistics		Speed	Travel Time	Delay Time	Stop Time
		MPH	hh:mm:ss	hh:mm:ss	hh:mm:ss
No Priority	1	9.1	0:19:53	0:14:49	0:10:05
	2	9.2	0:19:08	0:14:08	0:09:30
With Priority	1	10.2	0:17:54	0:12:50	0:08:34
	2	10.1	0:17:30	0:12:29	0:08:08
Average Change	1	1.10	- 0:01:59	- 0:01:59	- 0:01:31
	2	0.90	- 0:01:38	- 0:01:39	- 0:01:22
Average Change %	1	12.09%	-9.97%	-13.39%	-15.04%
	2	9.78%	-8.54%	-11.67%	-14.39%

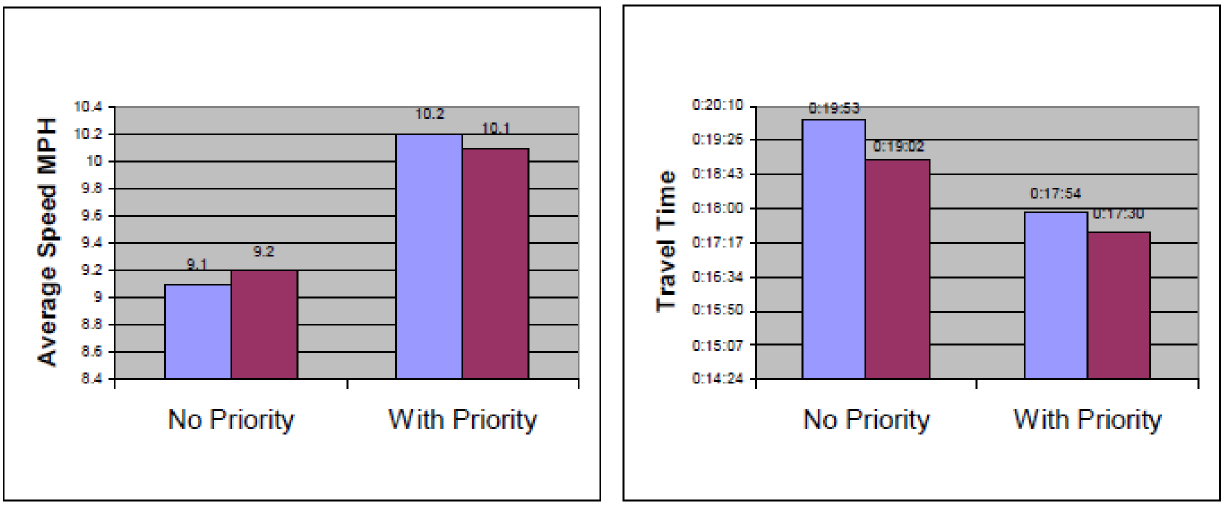

Figure 11. Travel time values, average network delay time, speed and flow at AM peak hours with green time added 10 seconds

An additional maximum green time scenario of 15 seconds was reviewed to further explore the potential for reducing vehicle travel time. The car travel time has dropped by about 2.5 minutes, 12% in EB. The average travel time of 1 minute (0.5 minutes) for an EB vehicle from an additional 10-second green scenario has already been discussed. By using the traffic light priority strategy with a maximum green spread of 15 seconds for these cars, travel time has dropped by about 12% in EB. The delay time for this car is reduced by about 16% ~ 19%.

Table 19. AM Peak statistics

Priority Extension Time = 15 sec					
AM PEAK Statistics		Speed MPH	Travel Time hh:mm:ss	Delay Time hh:mm:ss
No Priority	1	9.1	0:19:53	0:14:49
	2	9.2	0:19:08	0:14:08
With Priority	1	10.4	0:17:30	0:12:26
	2	10.7	0:16:27	0:11:27
Average Change	1	1.30	- 0:02:23	- 0:02:23
	2	1.50	- 0:02:41	- 0:02:41
Average Change %	1	14.29%	-11.99%	-16.09%
	2	16.30%	-14.02%	-18.99%

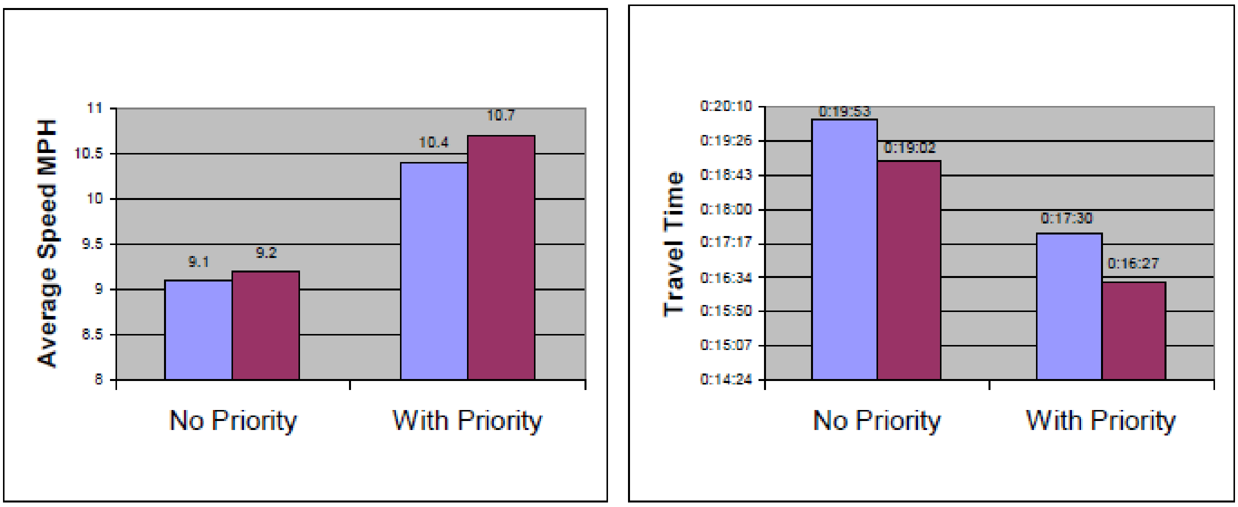

Figure 12. Travel time values, average network delay time, speed and flow at AM peak hours with green time added 15 seconds

The scenario of up to 20 seconds of extra green was also examined. However, the travel time of these cars did not decrease, but caused more traffic delay and stoppage.

3.6.2. PM Peak

As discussed earlier, there is a 40% increase in traffic at PM peak hours. The statistics of these cars are from the simulation with and without the traffic light priority strategy in the Table 20 for the peak hours of the PM. The time and speed of travel are also depicted in Figure 13. An additional maximum green additional time of 15 seconds was used to compare the effectiveness of the traffic light priority strategy with heavy traffic conditions compared to the AM peak period. At PM peak hours, it took about 22 (23) minutes for an EB vehicle to travel in the area surveyed without the priority of the time light. Using the traffic light priority strategy for these cars, travel time is reduced to 2 minutes in EB, or 10.5% in EB. The delay time is reduced by about 9% ~ 14%.

Table 20. PM Peak statistics

Priority Extension Time = 15 sec				
PM PEAK Statistics		Speed MPH	Travel Time hh:mm:ss	Delay Time hh:mm:ss
No Priority	1	8.3	0:21:58	0:16:55
	2	7.7	0:22:41	0:17:41
With Priority	1	9.2	0:19:39	0:14:35
	2	8.3	0:21:03	0:16:02
Average Change	1	0.90	- 0:02:19	- 0:02:20
	2	0.60	- 0:01:38	- 0:01:39
Average Change %	1	10.84%	-10.55%	-13.79%
	2	7.79%	-7.20%	-9.33%

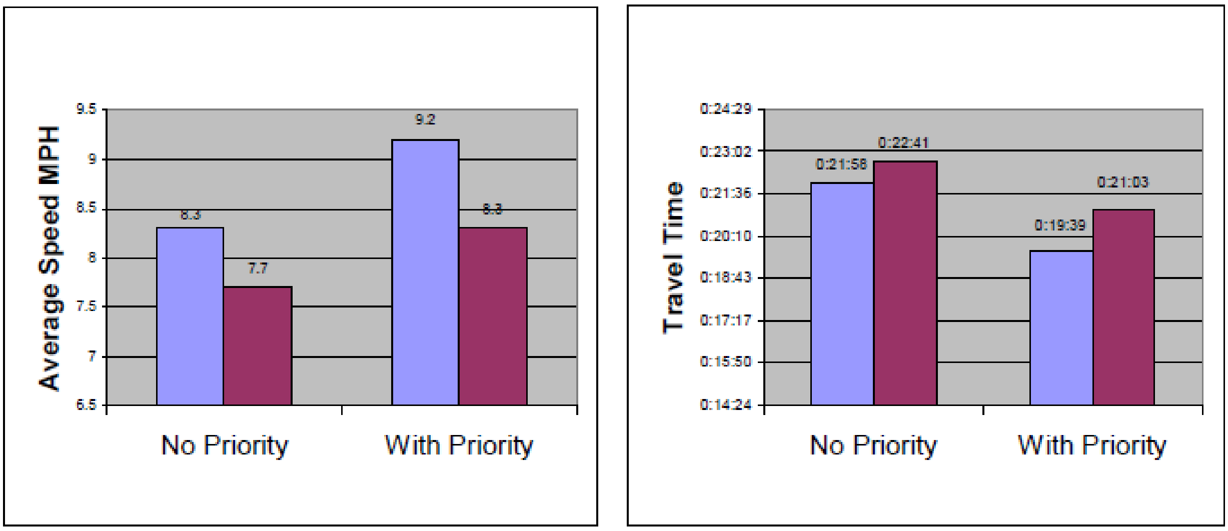

Figure 13. Travel time values, average network delay time, speed and flow at PM peak hours with green time added 15 seconds

3.7. Analysis of intended intersections

The main intersection criteria for effectiveness are analyzed and discussed. Thus, at the intersections of Farahani and Mirza Shirazi, who had previously had the LOS F at both peaks in the morning and afternoon, the survey was conducted. The average vehicle travel time and delay time in AM peak hours with the prioritization strategy, as presented in Table 21 and Table 22, have not changed. The average number of vehicles stopped in each vehicle is reduced by 0.03 stop per hour. During PM peak hours, 1.5 seconds and 1.0 seconds, the average travel time and vehicle delay will decrease.

Table 21. The statistics of intersections of Farahani and Mirza Shirazi at the AM peak

	AM Peak			
Intersection Statistics	**Flow** veh/h	**Speed** MPH	**Travel Time** mm:ss	**Delay Time** mm:ss
No Priority	606.50	24.59	00:57.5	01:20.0
With Priority	605.00	24.86	00:57.5	01:20.0
Average Change	-1.50	0.28	00:00.0	00:00.0
Average Change %	-0.25%	1.12%	0.00%	0.00%

Table 22. The statistics of intersections of Farahani and Mirza Shirazi at the PM peak

	PM Peak			
Intersection Statistics	**Flow** veh/h	**Speed** MPH	**Travel Time** mm:ss	**Delay Time** mm:ss
No Priority	675.00	25.78	01:01.0	01:26.0
With Priority	673.13	25.66	00:59.5	01:25.0
Average Change	-1.875	-0.11	- 00:01.5	- 00:01.0
Average Change %	-0.28%	-0.44%	-2.46%	-1.16%

3.8. General Network Analysis System

3.8.1. AM Peak

The statistics of the overall network system of the simulation with and without the traffic light strategy are listed in Table 23 and Table 24 for the AM peak hours. There is an average 7-second increase in travel time for 10 seconds and 15 seconds. The average delay was 7 seconds for the additional green time scenario of 10 seconds and the average delay of 6 seconds for the sub-scenario of 15 seconds increased. The average number of stops per vehicle increased by 0.1 stops per vehicle in both cases.

Table 23. Total network data at the AM peak with a green time added of 10 seconds

Priority Extension Time = 10 sec				
AM PEAK	Speed	Avg. Travel Time	Avg. Delay Time	Avg. Stops
Network Statistics	MPH	hh:mm:ss	hh:mm:ss	#/veh
No Priority	19.8	0:01:35	0:01:00	1.60
Priority	19.1	0:01:42	0:01:07	1.70
Average Change	-0.70	0:00:07	0:00:07	0.10

Table 24. Total network data at the AM peak with a green time added of 15 seconds

Overall Network System, Priority Extension Time = 15 sec				
AM PEAK	Speed	Avg. Travel Time	Avg. Delay Time	Avg. Stops
Network Statistics	MPH	hh:mm:ss	hh:mm:ss	#/veh
No Priority	19.8	0:01:35	0:01:00	1.60
Priority	19.1	0:01:42	0:01:06	1.70
Average Change	-0.70	0:00:07	0:00:06	0.10

3.8.2. PM Peak

As a result of the heavier traffic flow at PM peak hours, the overall network profile of the simulation with and without the traffic light strategy has delayed and further stopped the car. As noted in Table 25, the travel time in the PM peak period increased by 22 seconds per kilometer when the priority was given. The average delay increased by 23 seconds, while the average stop in each vehicle with the priority strategy increased by 0.6 stop per vehicle.

Table 25. Total network data at the PM peak with a green time added of 15 seconds

Overall Network System, Priority Extension Time = 15 sec				
PM PEAK	Speed	Avg. Travel Time	Avg. Delay Time	Avg. Stops
Network Statistics	MPH	hh:mm:ss	hh:mm:ss	#/veh
No Priority	18.1	0:01:55	0:01:19	2.00
Priority	16.0	0:02:17	0:01:42	2.60
Average Change	-2.10	0:00:22	0:00:23	0.60

4. CONCLUSION

Traffic along the path of Shahid Beheshti Street in the simulation model takes 44 seconds less than the observation trip at the peak hour on the western route. At PM hours, traffic in the simulation model on the Western route was 25 seconds shorter than travel time. In the western direction during peak hours of PM, the observed time was 43 seconds more than simulated time. The travel time of the AIMSUN simulator during the AM peak hours in the west was about 24 seconds longer than field observations. The overall statistics of the simulated network without the use of the priority traffic light strategy indicated that during the peak period (4-6 PM) traffic was much heavier than the morning hours (7-9 AM). There was a 40% increase in the flow of traffic at PM peak hours. The average speed in the system is reduced by 9% from 19.8 to 18 MPH compared to the AM period. The average travel time, delay time and stopping time in each vehicle at noon rush hour increased by 21%, 31.7% and 25%, respectively. The statistics of the vehicles concerned were calculated from the simulation with and without the traffic light priority strategy. Two cases were studied in the AM peak period. The maximum additional green length of 15 seconds and 10 seconds was respectively studied for comparing the reduction of travel time and traffic delay. It took about 20 (19) minutes for an EB vehicle to travel on Shahid Beheshti Street without the priority of the lights. Using the LED priority strategy with an extra green limit of 10 seconds for the vehicle, the travel time for this vehicle decreased by 2 minutes in EB, or 10% in EB. The delay time is reduced by about 11% ~ 13%. There is an average 7-second increase in travel time for 10 seconds and 15 seconds. The average delay time was 7 seconds for the additional green time scenario of 10 seconds and the average delay of 6 seconds for the sub-scenario of 15 seconds increased. The average number of stops per vehicle increased by 0.1 stops per vehicle in both cases.

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CONFLICT OF INTEREST

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