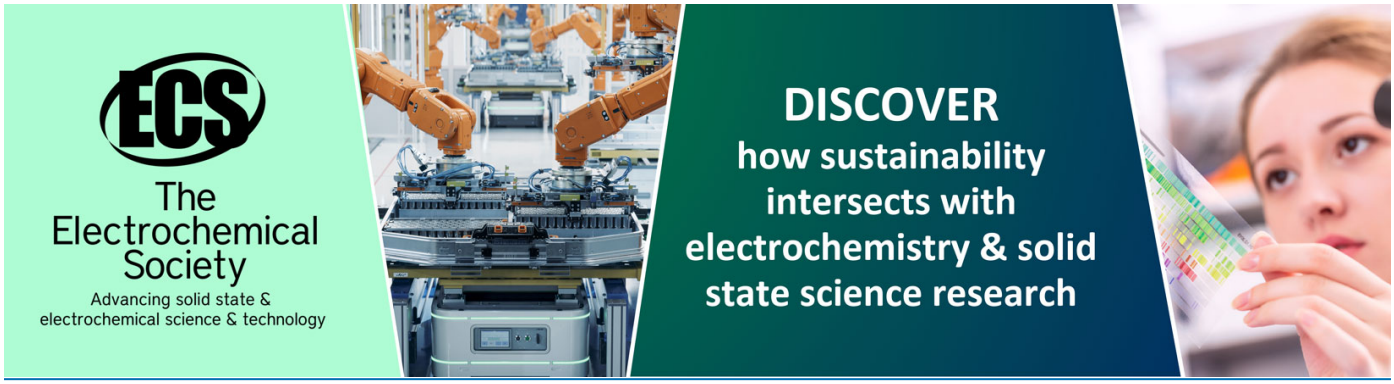
Improvement of the Traffic Management of Deactivated Al-Faris Al-Arabi Signalized Roundabout in Baghdad City



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Improvement of the Traffic Management of Deactivated Al-Faris Al-Arabi Signalized Roundabout in Baghdad City

Mahmood K J Al-Obaidi[1]
[1]Civil Engineering Department, Al-Farabi University College, Al-Daura Square, Al-Masafi Street, Baghdad, Iraq

Abstract. Baghdad city, the capital of Iraq has mainly suffered from influences of transportation highway modes especially at intersections. Traffic management system TMS leads to improve the level of service LOS of the intersections by reducing traffic congestion, delay and time wasted during travel. This research studied the improving of TMS for deactivated Al-Faris Al-Arabi signalized roundabout that considered the important area near city center. Traffic data collected manually by group of engineers during March and April, 2018. Highway Capacity Software HCS2010 used to assess and improve the TMS for current and future forecasted flow. Results showed that roundabout operating on LOS F with a high delay of time and saturation flow. Three solutions proposed to improve the traffic conditions considering of modifying the geometric features with changing and optimizing the timing plan of traffic signals. It showed a highly improving in LOS from F to B, improving saturation flow to less than one and reducing in delay time to about 43 times of that at existing conditions. In addition to analysis results, 18 years has been expected to carry the future forecasted data. Finally, architectural model has been achieved to display the pre and post improvement of the study area.

1. Introduction

An intersection is an area, joined of many roads that main purpose is to get a change in direction of the route. It vary in their geometrical features from a simple class, which just has two intersected roads at a right angle to the most complicated one, where three streets or more intersected in the same zone [1].
Some studies have been accomplished to find the problem solutions of signalized congested intersections. The purpose of the first one is to assess and develop the traffic managements at the Wadi-Saqra signalized intersections which is located in the western central part of the city of Amman in Jordan. It suffers from heavy congestion traffic flow with higher delay larger than any other areas in Amman. It analyzed by using HCM2000 Highway Capacity Manual and HCS2000 Highway Capacity Software. All intersection data were collected during the peak time intervals. The results showed that the delay of current flow is 473 sec/veh with LOS F. Four alternatives were analyzed to find the solutions to current and future congestions. The fourth one was chose to reduce the congestion and traveling cost for the public, and increase the efficiency and traffic operation of intersection [2].

The objectives of another study including traffic operation development for AL-Mustanseriyah roundabout in Baghdad city in Iraq. Data were collected manually by many observers, while HCS2000 is installed for the purpose of traffic analysis. It concluded that the flyover between Al-Mustanseriyah University and Al-Talebia Streets is the best choice to develop traffic performance of roundabout [3].
By using HCS2000 software, Al-Thawra signalized intersection in Al-Hilla city in Iraq has been found to operate at LOS F with a delay of 263.7sec/veh. So, improving the performance of an

intersection required separation of the traffic movements from conflicting with an overpass bridge. Data analysis explained that the intersection LOS is C with a delay of 22.8 sec/veh [4]. Another study included the capacity of traffic and performance of roundabouts, it found that behavior of the driver may influence mentioned traffic properties. I concluded that the best behavior modeling of gap-acceptance of drivers entering into a roundabout may gain more insighting for evaluation of roundabout operation [5].

2. Theoretical Background

The intersection is very important for simplifying traffic movements that leads to minimize of the traffic delay. This improvement has been done by alternate of the best geometric conditions which control the directions of vehicles in intersection with approximately fully safe. Every type of traffic junctions aim to provide priority attention for the drivers in each road section which prevent confusion and make flexibility in driving. Selection of the intersection type needs influencing of economic, environmental and operational factors on each proposed option [6].

Three important effectiveness characters are commonly checked to evaluate the traffic performance of signalized intersection: capacity, percent of volume-to-capacity (v/c) and delays. Capacity is a maximum flow of vehicles that pass through a given section of roadway during an hour under prevailing conditions; its evaluation by HCS based onprimary assumed values for saturated traffic flow, then it would be checked to simulate the realistic conditions. It takes in consideration for highway conditions same as the lanes number, lane width, grades and the lane objective use. According to the steps of HCM, capacity is evaluated for critical lane groups, which require the highest value of the green period. The v/c ratio is depended on critical and non-critical lane groups which do not influence the operation of traffic signal. It, also refer to as saturation degree of the traffic, and the adequacy of the facility to be equivalent for the vehicles demand. A percentage less than 85% indicate that enough capacity is to be computed and expecting of vehicles are not estimation affecting queues and delays. When it close to 100%, current traffic flow may become unstable condition, delay leads to be case of queuing. While, if it to be more than 100%, flow would be in an unstable case where a high delay would be occurred which leads to queuing case. According to all stated cases, vehicles ought to get more than one cycle length of signal to pass the intersection that is called a failure of signal cycle length [1].

Delay is the important effectiveness factor which is to be the main key for optimization of the traffic signals timing and estimation LOS required to drivers at signalized intersections as shown in table 1. In addition, it also is an element which is to be estimated due to containing delay related to decelerating to a stop, the stopped delay and other which related to accelerating from a stop. It can be assessed in different ways, the most commonly used forms is control delay which is including of stopped time delay, approach delay and travel time delay [7].

Table 1. LOS Definition based on delay (HCM)

LOS	Delay (veh/sec)
A	$d \leq 10$
B	$10 < d \leq 20$
C	$20 < d \leq 35$
D	$35 < d \leq 55$
E	$55 < d \leq 80$
F	$80 < d$

3. Study Objectives and Benefits

The objectives of the study are:

- Assessing the existing LOS at the deactivated signalized roundabout using HCS2010.
- Improving the operation management and traffic capacity of an existing features for current and future forecasted data by estimation the proper proposals.
- Architectural Model has been achieved for the proper alternative.

On the other hand, findings of this research will generate some benefits. Amongst which are:

- Studying the evaluation of signalized roundabout will help to develop the network performance, and the levels of accessibility and mobility.
- This study will also be as a main platform for other researchers to carry out more researches depended on the final recommendations.

4. Study Area

Al-Faris Al-Arabi signalized roundabout is the most significant intersection which lies in "Al-Karkh Side" in the capital Baghdad in Iraq. It joins between four important approaches closest to the Baghdad city center. Its place considered as an important location in Baghdad city. On the other hand, the finding of various public facilities and passing of mini buses cause to a highly flow rate which leads to delays especially at peak hour. Figure 1 illustrates the study area and main details by the GOOGLE MAPS.

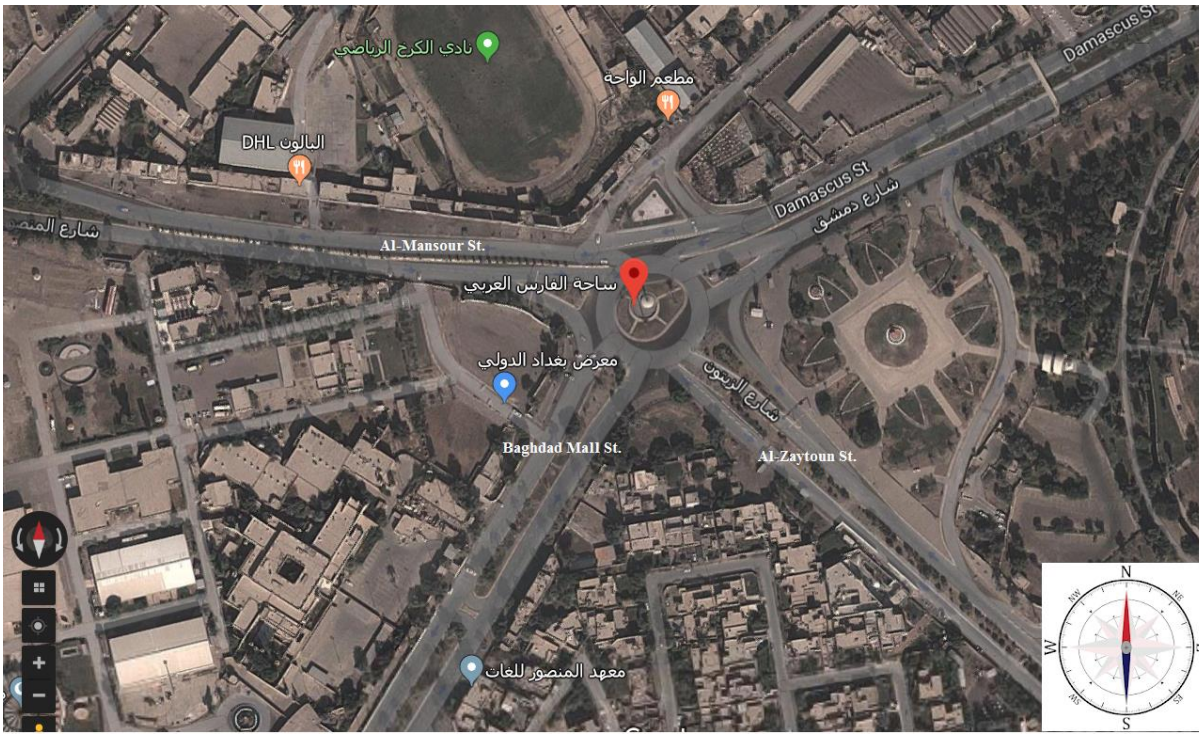

Figure 1. Satellite Image of Deactivated AL-Faris AL-Arabi Signalized Roundabout.

5. Data Collection

All required Data including geometric and traffic features were collected manually by a special team using the essential survey tools which considered as a suitable step to estimate the study purpose.

5.1. Geometric and Signals Operating Data

Due to deactivate of the traffic signals of Al-Faris Al-Arabi roundabout, the signal timing estimated depending on computing the maximum time for the cycle length for all approaches. Also, many kinds

of data sets has been collected such as roadway inventory details, number of lanes on roadways, lanes and medians width in all directions as shown in table 2.

Table 2. Geometric and Signals Operating Data**.**

Direction	Approach	Number of lanes	Movement	Width (m)	G (Sec)	Y (Sec)
Eastern North (E/N)	From Baghdad Mall street	1	L	3.5	175	0
		1	TH	3.5		
		1	R	3.5		
Western North (W/N)	From Zaytoun street	3	L	2.9	30	0
		3	TH	3.5		
		1	R	Exclusive		
Eastern south (E/S)	From AL-mansour street	3	L	3.5	160	0
		1	TH	3.3		
		1	R	3.3		
Western south (W/S)	From Damascus street	1	L	3.4	115	0
		2	TH	3.4		
		2	R	Exclusive		

5.2. Traffic Volume Data

The traffic volume data of deactivated signalized intersection were collected manually depending on assessing of traffic policeman to movement of vehicles during breaking down of traffic signals. The data were collected on March and April, 2017 during different workdays avoiding the holidays for three times per day, [(10:00 - 12:00 A.M), (2:00 – 4:00 P.M) and (6:30 – 8:30 P.M)] as shown in tables 3, 4, 5 and 6. The following data are needed for enhancing of the existing roundabout:

- V (veh/hr): Demand volume at peak hour
- PHF: Peak hour factor
- Hv (%): Percent of heavy vehicles

Vehicles are divided into small size which any of them moves on four tires contains passenger cars and mini buses, also large size which any of them moves on more than four tires.

Table 3. Traffic Data collected from Damascus Street**.**

Details	Time (hour)					
	10:00-11:00	11:00-12:00	2:00-3:00	3:00-4:00	6:30-7:30	7:30-8:30
L (pcph)	96	69	67	66	100	67
L (vph)	0	0	0	0	0	0
Hv (%)	0	0	0	0	0	0
PHF	0.82	0.78	0.88	0.91	0.80	0.79
TH (pcph)	1954	2016	1492	1377	1494	1181
TH (vph)	19	23	12	8	16	11
Hv (%)	3.818	4.5	3.308	2.437	4.01	3.56
PHF	0.98	0.99	0.89	0.84	0.82	0.86

Table 4. Traffic Data collected from Al-Mansour Street**.**

Details	Time (hour)					
	10:00-11:00	11:00-12:00	2:00-3:00	3:00-4:00	6:30-7:30	7:30-8:30
L (pcph)	406	436	580	556	377	401
L (vph)	4	3	3	1	1	1
Hv (%)	4.19	2.68	2.18	0.69	1.16	1.07
PHF	0.83	0.91	0.92	0.97	0.71	0.95
R (pcph)	574	566	942	898	389	373
R (vph)	4	3	5	3	2	2
Hv (%)	7.143	0	0	0	1.734	0
PHF	0.750	0.794	0.750	0.769	0.796	0.700
TH (pcph)	294	304	613	598	401	427
TH (vph)	0	0	0	0	0	0
Hv (%)	2.77	2.01	2.05	1.33	1.86	1.86
PHF	0.92	0.92	0.91	0.97	0.908	0.919

Table 5. Traffic Data collected from Baghdad Mall Street.

Details	Time (hour)					
	10:00-11:00	11:00-12:00	2:00-3:00	3:00-4:00	6:30-7:30	7:30-8:30
L (pcph)	678	703	1047	986	1399	1333
L (vph)	3	2	3	1	1	2
Hv (%)	1.73	1.00	1.11	0.41	0.27	0.59
PHF	0.89	0.83	0.96	0.97	0.90	0.98
R (pcph)	51	53	61	50	49	57
R (vph)	0	1	1	1	1	1
Hv (%)	0	7.69	6.25	5.55	5.55	7.14
PHF	0708	0.779	0.70	0.70	0.68	0.75
TH (pcph)	1440	1066	1235	1215	1292	1285
TH (vph)	21	18	18	10	12	12
Hv (%)	5.72	6.74	6.65	3.35	3.564	3.681
PHF	0.89	0.87	0.87	0.87	0.58	0.96

Table 6. Traffic Data collected from Al-Zaytoun Street.

Details	Time (hour)					
	10:00-11:00	11:00-12:00	2:00-3:00	3:00-4:00	6:30-7:30	7:30-8:30
L (pcph)	36	28	15	9	26	23
L (vph)	0	0	0	0	0	0
Hv (%)	0	0	0	0	0	0
PHF	0.69	0.63	0.53	0.56	0.67	0.63
R (pcph)	80	66	16	16	16	14
R (vph)	4	4	3	1	3	2
Hv (%)	17.04	21.72	56.66	16.66	41.66	49.99
PHF	0.70	0.72	0.79	0.708	0.70	0.70

TH (pcph)	514	540	425	376	553	534
TH (vph)	0	0	2	1	0	0
Hv (%)	0	0	1.78	1.17	0	0
PHF	0.95	0.95	0.94	0.93	0.97	0.94

6. Data Analysis and Discussion

An excel sheet was prepared to analyze the collected traffic data were mentioned previously to find the peak hour. From the traffic accounts of the field survey, time interval of [(2:00 - 3:00 P.M)] was assessed to be the peak hour. Summation of the traffic volumes during this hour was 6521 vph as shown in figure 2.

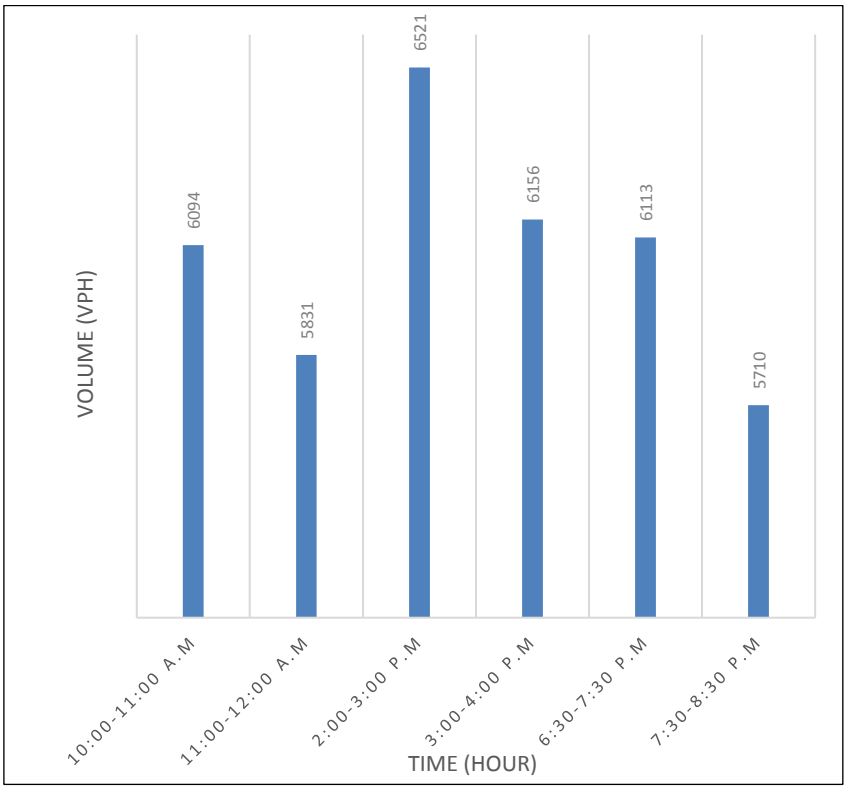

Figure 2. Traffic Data of Deactivated AL-Faris AL-Arabi Signalized Roundabout.

6.1. Assessment and Optimization of an Existing Features

Traffic data of an existing deactivated signalized roundabout are assessed and optimized using the HCS2010 as shown in table 7. Details of the software results of an existing feature before and after optimizing are mentioned in appendix A, figures A1 and A2.

Table 7. Assessment and Optimization of an Existing Features.

Proposals	Cycle Length (sec)	Amber Time (sec)	Rate of Current Volume (%)	LOS	Delay (sec/veh)
Existing	480.0	0	100	F	490.0
Optimization of Existing	230	4	100	F	443.3

6.2. Proposed Alternatives of the Traffic Signal Timing

In this case, the improvement of deactivated Al-Faris Al-Arabi signalized roundabout depended on decreasing the rate of current volume collected at peak hour in order to reach the cycle length to the specification range of more than or equal 30 sec and less than or equal 120 sec. The enhancement by using HCS2010 which include just proposing of optimization the signal timing, changed the LOS from F to C with a delay of 34.4 sec/veh and decreasing rate of 70% from the current volume as shown in table 8. This case gives a high improvements in LOS, but it operates just 30% of current volume; therefore, this proposal considered as unsuitable solution for enhancing of the roundabout. Details of the software results of the proposal No.8 are mentioned in appendix A, figures A3 and A4.

Table 8. Assessment of the proposed alternatives of the traffic signals timing.

Proposals	Cycle Length (sec)	Amber Time (sec)	Decreasing Rate of Current Volume (%)	LOS	Delay (sec/veh)
Proposal No.1	200	4	-10	F	333.3
Proposal No.2	210	4	-20	F	242.4
Proposal No.3	190	4	-30	F	183.6
Proposal No.4	180	4	-40	F	116.9
Proposal No.5	170	4	-50	E	72.3
Proposal No.6	190	4	-60	E	65.3
Proposal No.7	130	4	-65	D	49.3
Proposal No.8	80	4	-70	C	34.4

6.3. Proposed Alternatives of the Geometric Features and Traffic Signal Timing

In this case, the improvement of deactivated Al-Faris Al-Arabi signalized roundabout depended also on decreasing the rate of current peak volume to reach the cycle length to the specification range as mentioned previously, and it assumed to construct overpass (Grade Separated Structure) in two directions (two lanes per direction) along Demascus and Baghdad Mall Streets, 4-phases are actuated with an exclusive right lanes for the vehicles travelling from Demascus, Al-Mansour and Al-Zaytoun approaches. The enhancement by using HCS2010, changed the LOS from F to C with a delay of 34 sec/veh and decreasing rate of 65% from the current volume as shown in table 9. This case gives also a high improvements in LOS, but it operates just 35% of current volume; therefore, this proposal also considered as unsuitable solution for enhancing of the roundabout as in previous case. Details of the software results of the proposal No.11 are mentioned in appendix B, figures B1 and B2.

Table 9. Assessment of the proposed alternatives of geometric features (grade separated structure) and traffic signals timing.

Proposals	Cycle Length (sec)	Amber Time (sec)	Decreasing Rate of Current Volume (%)	LOS	Delay (sec/veh)
Proposal G.S	330	4	0	F	288.3
Optimization of G.S	300	4	-20	F	174.8
Proposal No.9	120	4	-40	F	98.0
Proposal No.10	110	4	-60	D	37.8
Proposal No.11	120	4	-65	C	34.0

On the other hand, In this case, the improvement of deactivated Al-Faris Al-Arabi signalized roundabout assumed to construct overpass (Y-Shape) with a normal level grade to distribute the traffic volume travelling from Baghdad Mall Street (3 lanes) to Demascus and Al-Mansour Streets (2 lanes for each street). Also, construction of overpass (Grade Separated Structure) with a high level grade to transport the traffic volume travelling from Demascus to Baghdad Mall Street (one direction with 2 lanes). It changed the LOS from F to B with a delay of 11.5 sec/veh and actuating of 3 phases instead of 4 and travelling of a full peak volume collected at deactivated conditions as shown in table 10. This case considered as a suitable solution for enhancing of the roundabout since it allows 100% of traffic flow to travel with a high LOS and little delay. Although, the cost is high as comparison to previous cases, but it gives an excellent solutions in current and future time. Details of the software results of the proposals NO.12 and No.13 are mentioned in appendix B, figures B3, B4, B5 and B6 respectively.

Table 10. Assessment of the proposed alternatives of traffic signals timing and geometric features (Y-shape with grade separated structure).

Proposals	Cycle Length (sec)	Amber Time (sec)	Number of Phases	LOS	Delay (sec/veh)
Proposal Y-Shape	480.0	0	4	F	826.5
Proposal No.12	100.0	4	4	B	17.1
Proposal No.13	90.0	4	3	B	11.5

Finally, proposal No.13 is considered as the best alternative among all previous mentioned proposals, because it show the improving in saturation flow to less than one and reducing in delay time to about 43 times of that at existing conditions. In addition, architectural model has been achieved to display the pre and post improvement of the study area as shown in figures 3 to 8.

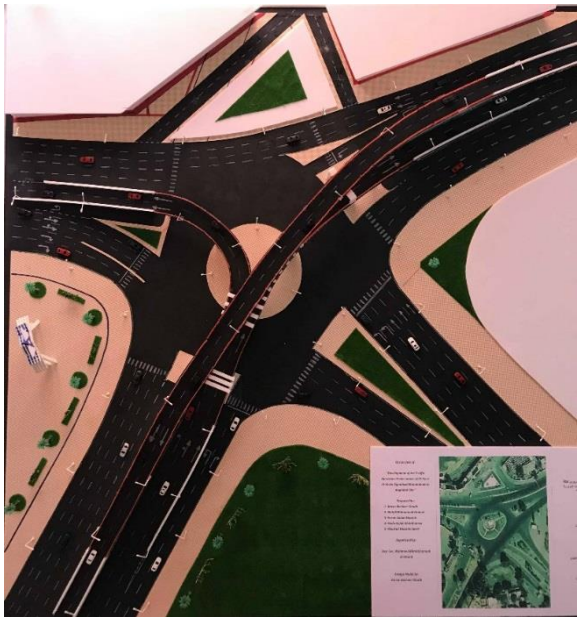

Figure 3. Top view for the signalized roundabout (proposal No.13).

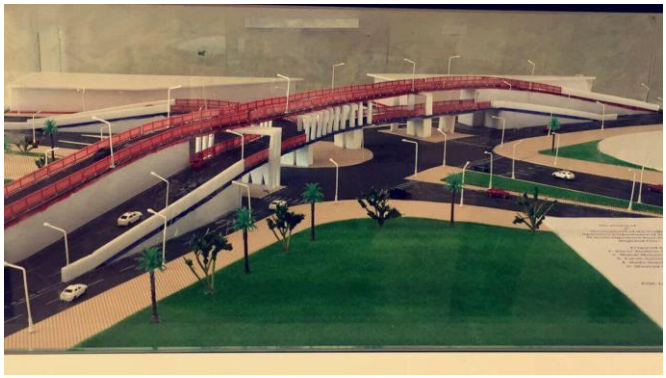

Figure 4. Side view for the signalized roundabout (proposal No.13).

Figure 5. Top view from Baghdad Mall Street (proposal No.13).

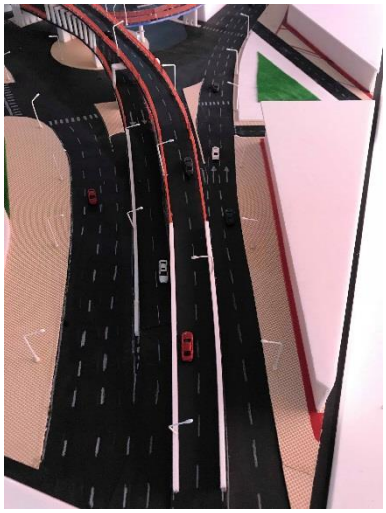

Figure 6. Top view from Demascus Street (proposal No.13).

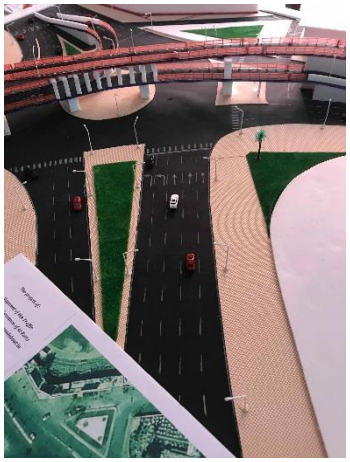

Figure 7. Top view from Al-Zaytoun Street (proposal No.13).

Figure 8. Top view from Al-Mansour Street (proposal No.13).

6.4. Analysis of Forecasted Future Data

Predicted data has been analyzed using HCS2010 by calculation of traffic capacity, delay and LOS for all intersection approaches. As comparison to all alternatives, proposal No.13 has been taken in consideration for checking the predicted interval of the traffic capacity to be in saturation case. Results showed that the capacity will arrive to its saturation state after 18 years later according to 3.5% of annual traffic growth rate as comply with [8], where the LOS and delay are F and 81.1 sec/veh respectively as mentioned in appendix B, figure B7.

7. Conclusions

In this study, the main conclusions that may be drawn are:

- Traffic data of an existing deactivated signalized roundabout are assessed and optimized using the HCS2010. Results showed that there is no different for an existing features before and after optimizing, since it stayed the LOS F with approximately the lower reduction in delay.
- the improvement of deactivated roundabout using HCS2010 which include just proposing of optimization the signal timing depended on decreasing the rate of current volume collected at peak hour in order to reach the cycle length to the specification range of more than or equal 30 sec and less than or equal 120 sec, changed the LOS from F to C with a delay of 34.4 sec/veh based on decreasing rate of 70% from the current volume. This case gives a high improvements in LOS, but it operates just 30% of current volume; therefore, the proposal No.8 considered as unsuitable solution for enhancing of the roundabout.
- The improvement of deactivated roundabout by using HCS2010 depended on changing the geometric features and signals timing; firstly, it assumed to construct overpass (Grade Separated Structure) in two directions (two lanes per direction) along Demascus and Baghdad Mall Streets, 4-phases are actuated with an exclusive right lanes for the vehicles travelling from Demascus, Al-Mansour and Al-Zaytoun approaches. The enhancement, changed the LOS from F to C with a delay of 34 sec/veh and decreasing rate of 65% from the current volume. This case gives also a high improvements in LOS, but it operates just 35% of current volume; therefore, the proposal No.11 also considered as unsuitable solution for enhancing of the roundabout. Secondly, It assumed to construct overpass (Y-Shape) with a normal level grade to distribute the traffic volume travelling from Baghdad Mall Street (3 lanes) to Demascus and Al-Mansour Streets (2 lanes for each street). Also, construction of overpass (Grade Separated Structure) with a high level grade to transport the traffic volume travelling from Demascus to Baghdad Mall Street (one direction with 2 lanes). It changed the LOS from F to B with a delay of 11.5 sec/veh and actuating of 3 phases instead of 4 and travelling of a full peak volume collected at deactivated conditions. The proposal No.13 considered as a suitable solution for enhancing of the roundabout since it allows 100% of traffic flow to travel with a high LOS and little delay. Although, the cost is high as comparison to previous cases, but it gives an excellent solutions in current and future time.

8. Recommendations

- Assessing the LOS for all streets that they join the roundabout using HCS software.
- Use another ways of surveying the traffic data such as video recording, GPS and GIS, then compare the results with that of this study.

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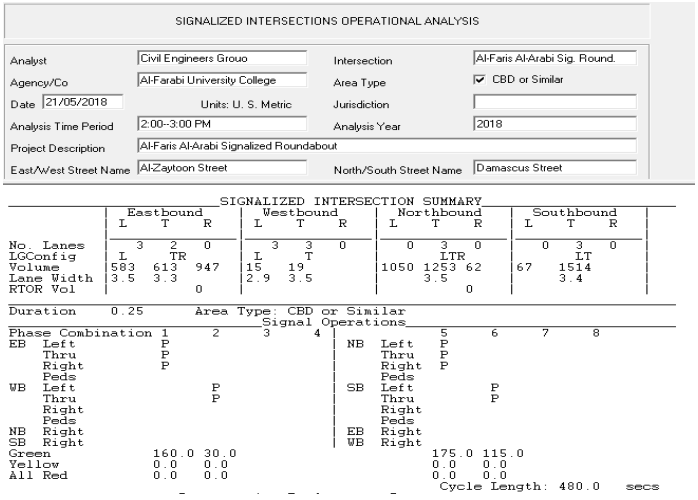
Appendix A



SIGNALIZED INTERSECTIONS OPERATIONAL ANALYSIS

Analyst	Civil Engineers Grouo	Intersection	Al-Faris Al-Arabi Sig. Round.
Agency/Co	Al-Farabi University College	Area Type	☑ CBD or Similar
Date	21/05/2018	Units: U. S. Metric	Jurisdiction	
Analysis Time Period	2:00--3:00 PM	Analysis Year	2018
Project Description	Al-Faris Al-Arabi Signalized Roundabout		
East/West Street Name	Al-Zaytoon Street	North/South Street Name	Damascus Street

SIGNALIZED INTERSECTION SUMMARY

	Eastbound			Westbound			Northbound			Southbound		
	L	T	R	L	T	R	L	T	R	L	T	R
No. Lanes	3	2	0	3	3	0	0	3	0	0	3	0
LGConfig	L	TR		L	T			LTR			LT	
Volume	583	613	947	15	19		1050	1253	62	67	1514	
Lane Width	3.5	3.3		2.9	3.5			3.5			3.4	
RTOR Vol			0						0			

Duration 0.25 Area Type: CBD or Similar

Signal Operations

Phase Combination	1	2	3	4		5	6	7	8
EB Left	P				NB Left	P			
Thru	P				Thru	P			
Right	P				Right	P			
Peds					Peds				
WB Left		P			SB Left		P		
Thru		P			Thru		P		
Right					Right				
Peds					Peds				
NB Right					EB Right				
SB Right					WB Right				
Green	160.0	30.0				175.0	115.0		
Yellow	0.0	0.0				0.0	0.0		
All Red	0.0	0.0				0.0	0.0		

Cycle Length: 480.0 secs

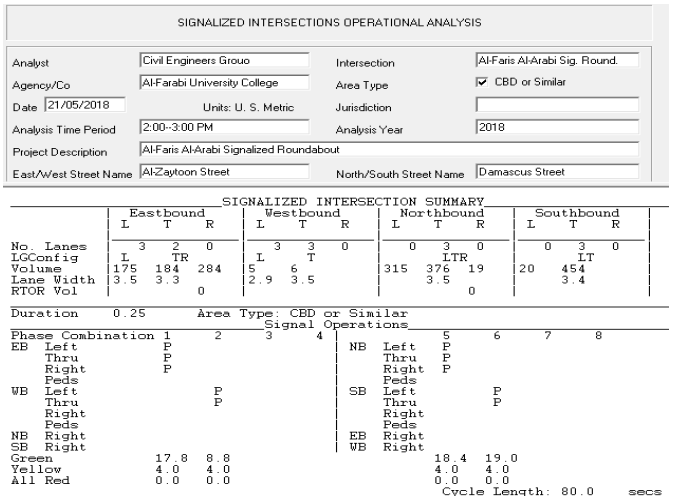
Figure A1. HCS2010 details of geometric and signal timing of an existing features before optimizing.

Intersection Performance Summary

Appr/ Lane Grp	Lane Group	Adj Sat Flow Rate (s)	Ratios v/c	Ratios g/C	Lane Group Delay	Lane Group LOS	Approach Delay	Approach LOS
Eastbound								
L	1424	4273	0.45	0.33	126.3	F		
TR	934	2803	2.07	0.33	646.9	F	518.5	F
Westbound								
L	254	4059	0.11	0.06	213.3	F		
T	281	4498	0.09	0.06	212.7	F	213.0	F
Northbound								
LTR	1560	4280	1.68	0.36	462.0	F	462.0	F
Southbound								
LT	1050	4383	1.69	0.24	498.2	F	498.2	F

Intersection Delay = 490.0 (sec/veh) Intersection LOS = F

Figure A2. HCS2010 details of delays and LOS of an existing features before optimizing.



SIGNALIZED INTERSECTIONS OPERATIONAL ANALYSIS

Analyst	Civil Engineers Grouo	Intersection	Al-Faris Al-Arabi Sig. Round.
Agency/Co	Al-Farabi University College	Area Type	☑ CBD or Similar
Date	21/05/2018	Jurisdiction	
Analysis Time Period	2:00--3:00 PM	Analysis Year	2018
Project Description	Al-Faris Al-Arabi Signalized Roundabout		
East/West Street Name	Al-Zaytoon Street	North/South Street Name	Damascus Street

Units: U. S. Metric

SIGNALIZED INTERSECTION SUMMARY

	Eastbound			Westbound			Northbound			Southbound		
	L	T	R	L	T	R	L	T	R	L	T	R
No. Lanes	3	2	0	3	3	0	0	3	0	0	3	0
LGConfig	L	TR		L	T			LTR			LT	
Volume	175	184	284	5	6		315	376	19	20	454	
Lane Width	3.5	3.3		2.9	3.5			3.5			3.4	
RTOR Vol			0						0			

Duration 0.25 Area Type: CBD or Similar

Signal Operations

Phase Combination	1	2	3	4		5	6	7	8
EB Left	P				NB Left	P			
Thru	P				Thru	P			
Right	P				Right	P			
Peds					Peds				
WB Left		P			SB Left		P		
Thru		P			Thru		P		
Right					Right				
Peds					Peds				
NB Right					EB Right				
SB Right					WB Right				
Green	17.8	8.8				18.4	19.0		
Yellow	4.0	4.0				4.0	4.0		
All Red	0.0	0.0				0.0	0.0		

Cycle Length: 80.0 secs

Figure A3. HCS2010 details of geometric and signal timing of the proposal No.8.

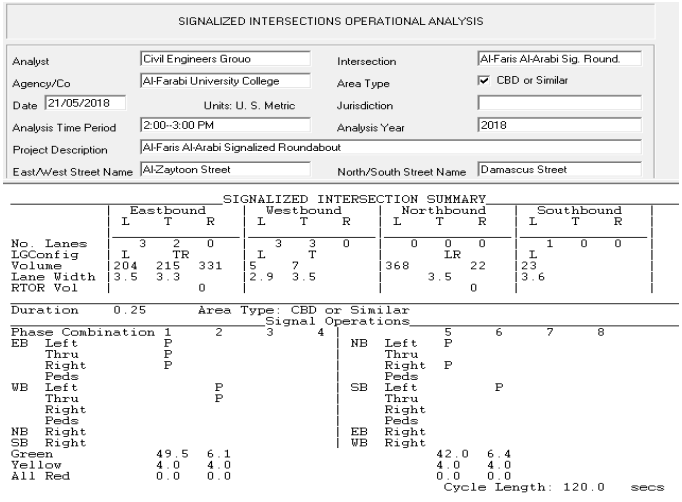
Intersection Performance Summary

Appr/ Lane Grp	Lane Group	Adj Sat Flow Rate (s)	Ratios v/c	Ratios g/C	Lane Group Delay	Lane Group LOS	Approach Delay	Approach LOS
Eastbound								
L	951	4273	0.20	0.22	25.8	C		
TR	628	2821	0.83	0.22	41.6	D	37.3	D
Westbound								
L	446	4059	0.01	0.11	31.8	C		
T	495	4498	0.01	0.11	31.8	C	31.8	C
Northbound								
LTR	986	4286	0.80	0.23	35.9	D	35.9	D
Southbound								
LT	1041	4383	0.51	0.24	28.2	C	28.2	C

Intersection Delay = 34.4 (sec/veh) Intersection LOS = C

Figure A4. HCS2010 details of delays and LOS of the proposal No.8.

Appendix B



SIGNALIZED INTERSECTIONS OPERATIONAL ANALYSIS

Analyst	Civil Engineers Grouo	Intersection	Al-Faris Al-Arabi Sig. Round.
Agency/Co	Al-Farabi University College	Area Type	☑ CBD or Similar
Date	21/05/2018	Jurisdiction	
Analysis Time Period	2:00--3:00 PM	Analysis Year	2018
Project Description	Al-Faris Al-Arabi Signalized Roundabout		
East/West Street Name	Al-Zaytoon Street	North/South Street Name	Damascus Street

Units: U. S. Metric

SIGNALIZED INTERSECTION SUMMARY

	Eastbound			Westbound			Northbound			Southbound		
	L	T	R	L	T	R	L	T	R	L	T	R
No. Lanes	3	2	0	3	3	0	0	0	0	1	0	0
LGConfig	L	TR		L	T			LR		L		
Volume	204	215	331	5	7		368		22	23		
Lane Width	3.5	3.3		2.9	3.5			3.5		3.6		
RTOR Vol			0						0			

Duration 0.25 Area Type: CBD or Similar

Signal Operations

Phase Combination	1	2	3	4		5	6	7	8
EB Left	P				NB Left	P			
Thru	P				Thru				
Right	P				Right	P			
Peds					Peds				
WB Left		P			SB Left		P		
Thru		P			Thru				
Right					Right				
Peds					Peds				
NB Right					EB Right				
SB Right					WB Right				
Green	49.5	6.1				42.0	6.4		
Yellow	4.0	4.0				4.0	4.0		
All Red	0.0	0.0				0.0	0.0		

Cycle Length: 120.0 secs

Figure B1. HCS2010 details of geometric and signal timing of the proposal No.11.

Intersection Performance Summary

Appr/ Lane Grp	Lane Group Capacity	Adj Sat Flow Rate (s)	Ratios v/c	Ratios g/C	Lane Group Delay	Lane Group LOS	Approach Delay	Approach LOS
Eastbound								
L	1763	4273	0.13	0.41	22.0	C		
TR	1164	2822	0.52	0.41	28.1	C	26.4	C
Westbound								
L	206	4059	0.03	0.05	54.4	D		
T	229	4498	0.03	0.05	54.4	D	54.4	D
Northbound								
LR	547	1563	0.79	0.35	46.2	D	46.2	D
Southbound								
L	87	1624	0.30	0.05	63.2	E		
							63.2	E

Intersection Delay = 34.0 (sec/veh) Intersection LOS = C

Figure B2. HCS2010 details of delays and LOS of the proposal No.11.

SIGNALIZED INTERSECTIONS OPERATIONAL ANALYSIS

Analyst	Civil Engineers Grouo	Intersection	Al-Faris Al-Arabi Sig. Round.
Agency/Co	Al-Farabi University College	Area Type	☑ CBD or Similar
Date	21/05/2018	Units: U. S. Metric	Jurisdiction	
Analysis Time Period	2:00-3:00 PM	Analysis Year	2018
Project Description	Al-Faris Al-Arabi Signalized Roundabout		
East/West Street Name	Al-Zaytoon Street	North/South Street Name	Damascus Street

SIGNALIZED INTERSECTION SUMMARY

	Eastbound L	Eastbound T	Eastbound R	Westbound L	Westbound T	Westbound R	Northbound L	Northbound T	Northbound R	Southbound L	Southbound T	Southbound R
No. Lanes	2	1	0	2	3	0	0	0	2	1	0	0
LGConfig	L	T		L	T				R	L		
Volume	583	613		15	19				62	67		
Lane Width	3.5	3.5		4.8	4.8				3.6	3.6		
RTOR Vol									0			

Duration 0.25 Area Type: CBD or Similar

Signal Operations

Phase Combination	1	2	3	4	5	6	7	8
EB Left	P				NB Left			
Thru	P				Thru			
Right					Right	P		
Peds					Peds			
WB Left		P			SB Left	P		
Thru		P			Thru			
Right					Right			
Peds					Peds			
NB Right					EB Right			
SB Right					WB Right			
Green		66.0	6.0			6.0	6.0	
Yellow		4.0	4.0			4.0	4.0	
All Red		0.0	0.0			0.0	0.0	

Cycle Length: 100.0 secs

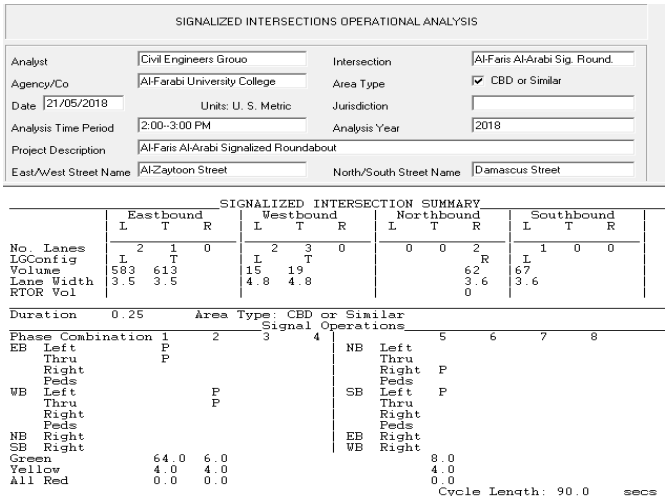
Figure B3. HCS2010 details of geometric and signal timing of the proposal No.12.

Intersection Performance Summary

Appr/ Lane Grp	Lane Group Capacity	Adj Sat Flow Rate (s)	Ratios v/c	Ratios g/C	Lane Group Delay	Lane Group LOS	Approach Delay	Approach LOS
Eastbound								
L	2006	3040	0.32	0.66	7.8	A		
T	1081	1638	0.63	0.66	12.7	B	10.3	B
Westbound								
L	213	3547	0.08	0.06	45.1	D		
T	309	5155	0.07	0.06	44.8	D	44.9	D
Northbound								
							56.0	E
R	146	2427	0.47	0.06	56.0	E		
Southbound								
L	97	1624	0.76	0.06	89.0	F		
							89.0	F

Intersection Delay = 17.1 (sec/veh) Intersection LOS = B

Figure B4. HCS2010 details of delays and LOS of the proposal No.12.



SIGNALIZED INTERSECTIONS OPERATIONAL ANALYSIS

Analyst	Civil Engineers Grouo	Intersection	Al-Faris Al-Arabi Sig. Round.
Agency/Co	Al-Farabi University College	Area Type	☑ CBD or Similar
Date	21/05/2018	Units: U. S. Metric	Jurisdiction	
Analysis Time Period	2:00--3:00 PM	Analysis Year	2018
Project Description	Al-Faris Al-Arabi Signalized Roundabout		
East/West Street Name	Al-Zaytoon Street	North/South Street Name	Damascus Street

SIGNALIZED INTERSECTION SUMMARY

	Eastbound			Westbound			Northbound			Southbound		
	L	T	R	L	T	R	L	T	R	L	T	R
No. Lanes	2	1	0	2	3	0	0	0	2	1	0	0
LGConfig	L	T		L	T				R	L		
Volume	583	613		15	19				62	67		
Lane Width	3.5	3.5		4.8	4.8				3.6	3.6		
RTOR Vol									0			

Duration 0.25 Area Type: CBD or Similar

Signal Operations

Phase Combination	1	2	3	4	5	6	7	8
EB Left		P			NB Left			
Thru		P			Thru			
Right					Right	P		
Peds					Peds			
WB Left			P		SB Left	P		
Thru			P		Thru			
Right					Right			
Peds					Peds			
NB Right					EB Right			
SB Right					WB Right			
Green		64.0	6.0			8.0		
Yellow		4.0	4.0			4.0		
All Red		0.0	0.0			0.0		

Cycle Length: 90.0 secs

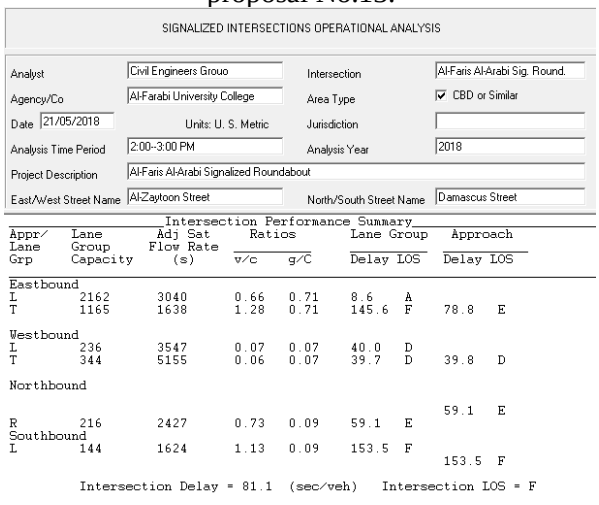
Figure B5. HCS2010 details of geometric and signal timing of the proposal No.13.

Intersection Performance Summary

Appr/ Lane Grp	Lane Group	Adj Sat Flow Rate	Ratios		Lane Group		Approach	
	Capacity	(s)	v/c	g/C	Delay	LOS	Delay	LOS
Eastbound								
L	2162	3040	0.30	0.71	5.1	A		
T	1165	1638	0.58	0.71	8.6	A	6.9	A
Westbound								
L	236	3547	0.07	0.07	40.0	D		
T	344	5155	0.06	0.07	39.7	D	39.8	D
Northbound								
							42.3	D
R	216	2427	0.32	0.09	42.3	D		
Southbound								
L	144	1624	0.51	0.09	51.6	D		
							51.6	D

Intersection Delay = 11.5 (sec/veh) Intersection LOS = B

Figure B6. HCS2010 details of delays and LOS of the proposal No.13.



SIGNALIZED INTERSECTIONS OPERATIONAL ANALYSIS

Analyst	Civil Engineers Grouo	Intersection	Al-Faris Al-Arabi Sig. Round.
Agency/Co	Al-Farabi University College	Area Type	☑ CBD or Similar
Date	21/05/2018	Units: U. S. Metric	Jurisdiction	
Analysis Time Period	2:00--3:00 PM	Analysis Year	2018
Project Description	Al-Faris Al-Arabi Signalized Roundabout		
East/West Street Name	Al-Zaytoon Street	North/South Street Name	Damascus Street

Intersection Performance Summary

Appr/ Lane Grp	Lane Group	Adj Sat Flow Rate	Ratios		Lane Group		Approach	
	Capacity	(s)	v/c	g/C	Delay	LOS	Delay	LOS
Eastbound								
L	2162	3040	0.66	0.71	8.6	A		
T	1165	1638	1.28	0.71	145.6	F	78.8	E
Westbound								
L	236	3547	0.07	0.07	40.0	D		
T	344	5155	0.06	0.07	39.7	D	39.8	D
Northbound								
							59.1	E
R	216	2427	0.73	0.09	59.1	E		
Southbound								
L	144	1624	1.13	0.09	153.5	F		
							153.5	F

Intersection Delay = 81.1 (sec/veh) Intersection LOS = F

Figure B7. HCS2010 details of geometric and signal timing of the proposal No.13 at future time.