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EVALUATION OF TRAFFIC FLOW AND TRAFFIC NETWORK MANAGEMENT SYSTEM IN JORDAN

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ABSTRACT: *Amman city, the capital of Jordan has suffered from the impacts of highway mode of transportation. Traffic network management system aim to reduce traffic congestion, delay, fuel consumption, and air and noise pollution. Also, to improve the level of service (LOS) of the urban streets and intersections. This research paper is an engineering project management study; it is about improving traffic network management system in Al Shmesani district in Amman. It was conducted on a network of two main arterials with eight signalized intersections. They are Al Kindi street continued with Prince Shaker Bin Zaid street and Al Sharif Naser Bin Jamel street. The traffic data was collected from the government records at several departments in Amman Municipality and Directorate of Public Security. Highway Capacity Software HCS2000 and updated Synchro-8 programs software were used to evaluate the traffic conditions at each intersection for years 2012 and 2022. The evaluation shows that the intersections are operating at LOS F with high delay time and high saturation flow. Two alternatives were used to improve the traffic conditions. The first one is to change the existing timing plan of the traffic signal to optimize timing plan, this showed little improvement in traffic condition. The second alternatives are to modify the geometric conditions with changing and optimizing the timing plan of the signalized intersections. It showed good improving in the traffic conditions and saving in delay time and fuel consumption at the existing and the future conditions. The Level of Service LOS's of the intersections were improved from LOS F to LOS C, D and E. It showed also the average overall saving in vehicle delay is about 87.75% and the saturation flow is improved at all intersections to less than one. The fuel consumption is also reduced with about 93%.*

KEYWORDS: Highway Mode of Transportation, Traffic Network Management System, Traffic Congestion, Delay, Fuel Consumption, Air Pollution, Noise Pollution, Level of Service (LOS), Urban Streets, Signalized Intersections, Saturation Flow.

INTRODUCTION

Engineering Project Management (EPM) is one of the most important types of management, such as construction of housing, buildings, highways, bridges and other civil engineering projects. The success of any of these projects depends primarily on the degree of active management based on planning and monitoring of project activities. The task of management is not limited to a certain stage of the project. It starts since the beginning of the preparation of the project and ends when the project achieves the purpose and goal of it (Al Ameri 2007).

In recent years emphasis in transportation planning has shifted from long-term, capital investment, capacity-increasing construction projects to short-term, relatively low-cost

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projects aimed at using existing transportation facilities more efficiently. The importance of energy conservation and environmental-impact analysis is also being stressed. This trend in the transportation engineering field placed heavy emphasis on Transportation System Management (TSM) as part of the planning process and as a prerequisite for improvements to increase the capacity of the Urban Transportation System (Jrew 1985, UMTA, FHWA 1975).

Problem Definition

Amman, the capital of the Hashemite Kingdom of Jordan, like many other cities in the world is suffering from a great pressure on its roadways, facing many problems in traffic network system. It needs constantly to evaluate and identify existing problems and to find solutions to them (Great Amman Municipality 2013).

As part of Amman city, Al-Shmesani district have problems of congestion and traffic jams that occur during peak hour, making delay to the users of the network, increase of the fuel consumption, and increases the air pollution.

The study will focus on certain network in Al-Shmesani district to achieve the best results to solve such problems. The network is consisting of two main arterials with eight signalized intersections that are located at the selected network.

Study Objectives

The main objectives of this research study are:

1 Evaluating the existing and the future traffic conditions (year 2012 and year 2022) of the network system by using HCS2000 and Synchro-8 computer software.
2 Improving the traffic network management system by optimizing the existing and future traffic conditions by using Synchro-8 computer software.
3 Improving the traffic network management system by modifying the geometric and traffic signal for the existing and future traffic conditions by using Synchro-8 computer program.

Traffic Condition Data

Engineering management of any transportation project requires good decision making in term of analysis, evaluating, planning, and optimizing of the existing transportation system. The traffic network system in urban areas of any city must be evaluated for short and long term planning. The traffic network system includes unsignalized and signalized intersections and also may include roundabout and interchange intersections.

The geometric and traffic condition data should be identified for the present and future based on recorded growth of traffic volume. Congestion of traffic volume may be developed due to the increase of economic growth.

Study Area

The selected study area is a network of two arterials in Al-Shmesani district. The first arterial with four intersections and the second arterial with five intersections are connected together in Wadi Saqra intersection.

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The first arterial is Al-Kindi Street which is connected with Prince Shaker Bin-Zaid street, with five intersections, they are:

1. Al Kindi intersection (Intersection one)
2. Wadi Saqra intersection (Intersection two)
3. Wahbah Tamari intersection (Intersection three)
4. Villa Roza intersection (Intersection four)
5. Arabic Bank intersection (Intersection five)

The second arterial is Al Sharif Naser Bin-Jameel Street, with four intersections, these intersections are:

1. Wadi Saqra intersection (Intersection two)
2. Abu Anz1 intersection (Intersection six)
3. Abu Anz 2 intersection (Intersection seven)
4. Al Comodor intersection. (Intersection eight)

LITERATURE REVIEW

Many researches have been taken place on the subject of improving of the traffic network management system in Amman city or in other Jordanian cities or in other countries. All these researches aim to improve the existing traffic network to insure that it will carry the future traffic demand.

Abojaradeh et al. (2014), studied the operational analysis of Wadi- Saqra signalized intersection in Amman area. The intersection has heavy traffic volume, with higher delay and heavy congestion traffic more than any other similar intersections in Amman.

The intersection was analyzed as an isolated signalized intersection by using HCM (Highway Capacity Manual) and HCS (Highway Capacity Software). Synchro-6 computer program was also used for the improvement through optimization process. The geometric, traffic and signalized data were collected during the morning and afternoon peak time periods. The results indicated that the current delay was 473 sec/veh with Level of Service F (LOS-F). Four alternatives were recommended to solve the current and future problems. The recommended alternatives are prohibit left turning at all approaches, optimization of the existing traffic signals, construct one through overpass for one direction, and construct two overpass or one overpass and tunnel for two directions.

The first three alternatives were not able to reduce the level of service significantly. On the other hand, the fourth alternative will improve the level of service from (F) with 473 sec/veh delay to LOS C with 27 sec/veh delay with optimum cycle length 90 seconds instead of 190 seconds. The estimated initial cost of constructing two over pass was about 30,000,000 JD with annual saving of 8,371,740 JD (abojaradeh et al. 2014).

Al-Omari B. et al. (2007), have a research to validate the Highway Capacity Software (HCS) and the Signalized Intersection Design and Research Aid (SIDRA) Software which are widely used for estimating delay at signalized intersections in Jordan.

By collecting of fifty four hours of data from eighteen legs at five signalized intersections in Irbid city; the second largest city in Jordan. Traffic volume and control delay during peak and

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off-peak periods were measured by using video cameras. Data on geometric design elements, signal timing and phasing, and vehicular speeds were measured through field survey.

The results of the analysis showed that, for low delay ranges, HCS tends to slightly over-estimate control delay; while SIDRA has a predicted control delay that is in good agreement with the field data. At higher delay levels, HCS has noticeable scattered predictions as compared to field data with more tendencies to over-estimation, while SIDRA provides less scattering than HCS. It was found that the two models can be improved significantly by calibrating bus PCE (passenger car equivalent) factor or the basic saturation flow rate. However, the best improvement could be obtained by calibrating both the basic saturation flow rate and bus PCE factor, simultaneously. It can be concluded that the two softwares can be used for traffic analysis in Jordanian conditions after calibrating both the saturation flow rate and bus PCE factor. However, SIDRA showed a better performance than HCS. The study showed that traffic software, which are being used in the developed countries, should not be used in Jordan or other developing countries before calibrating their parameters that are believed to be different from those in developed countries such as the ones related to driver behavior (Al-Omari et al. 2007).

Karim Q. (2011), from Al-Mustanseriyah University, Baghdad – Iraq, studied Al-Quds intersection in Baghdad. The intersection is a T-intersection with three (legs) main roads. The main objectives of the research are to evaluate traffic performance operation in Al-Quds signalized intersection, finding the Existing LOS, suggesting the best proposed geometric design at study area to achieve a suitable LOS at the present time and future.

By using the Highway Capacity Software (HCS2000), the intersection was found to be working at LOS F with average delay of 328.7 sec/veh. The researcher suggests adding one distributor lane, making the intersection quadrant one, with four (legs) main roads. The LOS was improved to LOS C with 34.6 sec/veh delay. The researcher found that with the suggested geometric design of the intersection the LOS will achieve E level with 80.0sec/veh after 11 years (Karim 2011).

Awad H. A. et al. (2010), Al-Anbar University – Iraq, in 2010 have studied the "Evaluation and Improvement of Traffic Operation for Al-Zeoat Intersection in Al-Ramadi city". By using SIDRA traffic program, it was found that the existing level of service Al-Zeoat intersection is LOS F with delay of 84.7sec/veh. It has been concluded that, fly over at the main path of traffic movement at Al-Zeoat intersection (Al-Mohafadha St. –Al-Mahkama St.) is the best proposal to improve the capacity and traffic operation in Al-Zeoat intersection.By adopting this proposal, the expected average delay at base year is (34.1) sec/veh. This delay will make the intersection work under LOS C (Awad et al. 2010).

Al-Ubaidy A. et al. (2007), from University of Technology, Baghdad – Iraq. In 2007, they had a study of "Evaluation The Performance of Al-Thawra At-Grade Intersection Using The HCS2000 Computer Package". By using HCS2000 software, the researchers found that Al-Thawra signalized intersection in Al-Hilla city – Iraq, is working at LOS F with an intersection delay value of 263.7sec/veh. Therefore, and because of the reasons above, it is important to improve the performance of Al-Thawra Intersection by separate the conflicting traffic movements with an overpass bridge. The traffic survey shows that the high traffic volume of through movement of the North-South direction has the major effect on the intersection. Therefore, the North-South is the suitable direction to construct the suggested bridge overpass to separate the through traffic of this direction from the other movements of

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the intersection. The results indicate that the intersection LOS C with an intersection delay of 22.8sec./veh (Al-Ubaidy et al. 2007).

Roshandeh A. (2012), studied the saturation flow at traffic signal using TRANSYT: a case study in johor Bahro in Malaysia, the study area was at the signalized intersection of Jalan Pendidikan-Jalan Perdagangan, Skudia. By using TRANSYT software it was found that the test signalized intersection has acceptable headway, saturation and lost time. The major arm of the intersection has LOS C while minor arm has LOS D, which was still acceptable. The existing traffic demand is still less than the intersection capacity, which means that the flow in this intersection is still not oversaturated yet. Therefore, no upgrading is needed for this intersection for this time being. However, since minor arm has high delay, attention need to be given to this arm since it was connected to the nearest third intersection to reduce the probability of getting worst LOS and delay.

For future studies, it was recommended to measure headway, lost time and saturation flow rate for all arms of this intersection. Besides, survey should be done to all three intersections to determine the correlation signal settings and control for all intersections. This is essential to ensure that these three intersections perform efficiently, which directly decrease the delay and increase the safety at these intersections (Roshandeh 2012).

Al-Masaeid, H. R. (1999), studied the capacity and performance of roundabouts, it was found that driver behavior can affect the capacity and performance of the road or the intersection, the study found that an efficient modeling of gap-acceptance behavior of drivers entering into a roundabout would provide more insight for assessing roundabout operation (Al-Masaeid 1999).

EVALUATION OF EXISTING TRAFFIC NETWORK SYSTEM

Intersection One (Al Kindi Intersection)

Al Kindi intersection is a signalized intersection with three legs connecting two main arterials, Al Kindi street with Mekka street. The traffic flow at this intersection arrives to three approaches, two approaches from Al Kindi street and the third from Mekka street. The intersection signal is operated at 110 seconds cycle length with three split phases. There is no U-turn in Al Kindi street through the signalized intersection, it is only in Mekka street.

Table 1 show that the intersection is operating at LOS – F, with high intersection delay (103.6 sec/veh at HCS2000 and 101.1 sec/veh at Synchro-8. The existing data was evaluated by using HCS2000 and Synchro-8 programs. The degree of saturation is also high (V/C >1), the intersection is oversaturated.

Table 1: Comparison results for the existing condition of intersection 1

	HCS 2000				Synchro-8			
Approach	EB	WB	NB	SB	EB	WB	NB	SB
Delay (Sec/veh)	37.2	-	136.0	120.2	37.6	-	131.7	117.5
LOS	D	-	F	F	D	-	F	F
Intersection								
Intersection Delay	103.6				101.1			

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(Sec/veh)		
Intersection LOS	F	F
Cycle length (Sec)	110	110
Intersection v/c ratio	1.13	1.59
Fuel Used (l/h)	-	956

Intersection Two (Wadi Saqra Intersection)

Wadi Saqra intersection is the common intersection between the two arterials of the study area. It is four legs signalized intersection, connecting Al Sharif Nasir Bin Jamil Street from the north and Arrar Street from the south with Al Kindy Street from the west and Prince Shaker Bin Zaid Street from the west. The traffic flow at this intersection arrives to four approaches, each approach with five lanes, which are used for through, left and U-turn movements. There is U-turn with the left turn for each Approach of the intersection. The right turn is exclusive with separate lane at the four approaches. The intersection traffic signal is operated at 190 seconds cycle length with four split phases.

Table 2 shows that the intersection is operating at LOS - F with high intersection delay (157.4 sec/veh at HCS2000 and 147.0 sec/veh at Synchro-8) the degree of saturation is also high (V/C >1), the intersection is oversaturated.

Table2: Comparison results for the existing condition of intersection 2

	HCS 2000				Synchro-8			
Approach	EB	WB	NB	SB	EB	WB	NB	SB
Delay (Sec/veh)	107.7	293.6	125.4	108.2	102.7	267.1	118.4	104.7
LOS	F	F	F	F	F	F	F	F
Intersection								
Intersection Delay (Sec/veh)	157.4				147.0			
Intersection LOS	F				F			
Cycle length (Sec)	190				190			
Intersection v/c ratio	1.23				1.53			
Fuel Used (l/h)	-				1297			

Intersection Three (Wahbah Tamari Intersection)

Wahbah Tamari intersection is a signalized with four legs intersection, connecting the Prince Nasir Bin Jamil Street with Sate'e Al Hosary street.

The traffic flow at this intersection will arriveto all approaches, but one of the Approaches (SB) with no through or left turn movement, it is with right turn movement only. The intersection signal is operated at 135 seconds cycle length with three split phases. U-turn is not allowed in this intersection.

Table 3 shows that the intersection is operating at LOS - F with high intersection delay (193.0 sec/veh at HCS2000 and 184.6 sec/veh at Synchro-8) the degree of saturation is also high (V/C >1), the intersection is oversaturated.

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Table 3: Comparison results for the existing condition of intersection 3

	HCS 2000				Synchro-8			
Approach	EB	WB	NB	SB	EB	WB	NB	SB
Delay (Sec/veh)	308.3	106.9	53.9	44.4	295.7	103.0	50.9	37.7
LOS	F	F	D	D	F	F	D	D
Intersection								
Intersection Delay (Sec/veh)	193.0				184.6			
Intersection LOS	F				F			
Cycle length (Sec)	135				135			
Intersection v/c ratio	1.20				1.58			
Fuel Used (l/h)	-				776			

Intersection Four (Villa Roza Intersection)

Villa Rosa intersection is a signalized with three legs intersection connecting two main street in Al Shmesani district, Prince Nasir Bin Jamil Street and Al Sharif Abdulhamid Sharaf street. The traffic flow at this intersection arrives to all approaches. The intersection signal is operated at 110 seconds cycle length with three split phases. the U-turn is allowed only for Al Sharif Abdulhamid Sharaf street; the EB approach. The right turn is exclusive with separate lane as shown in Figure 15.

Table 4 shows that the intersection is operating at LOS - D with intersection delay (40.3 sec/veh at HCS2000 and Synchro-8); the degree of saturation (V/C) is 0.91 at HCS2000 and 1.14 at Synchro-8 program.

Table 4: Comparison results for the existing condition of intersection 4

	HCS 2000				Synchro-8			
Approach	EB	WB	NB	SB	EB	WB	NB	SB
Delay (Sec/veh)	37.9	42.4	-	42.8	37.2	43.0	-	43.1
LOS	D	D	-	D	D	D	-	D
Intersection								
Intersection Delay (Sec/veh)	40.3				40.3			
Intersection LOS	D				D			
Cycle length (Sec)	110				110			
Intersection v/c ratio	0.91				1.14			
Fuel Used (l/h)	-				285			

Intersection Five (Arabic Bank Intersection)

Arab Bank intersection is a signalized with four legs intersection, connecting Prince Nasir Bin Jamil Street with Ahmad Faris Al Shadiak street from the south and Al Shaikh Yousif Al Aseer street from the north. The traffic flow at this intersection arrives to four approaches. U-turn is not allowed in this intersection. Right turn is exclusive with separate lane from Al

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Shaikh Yousif Al Aseer street only. The intersection traffic signal is operated at 90 seconds cycle length with three split phases.

Table 5 shows that the intersection is operating at LOS - F with high intersection delay (199.9 sec/veh at HCS2000 and 194.8 sec/veh at Synchro-8); the degree of saturation is also high, (V/C) is 0.88 at HCS2000 and 1.43 at Synchro-8 program.

Table 5: Comparison results for the existing condition of intersection 5

	HCS 2000				Synchro-8			
Approach	EB	WB	NB	SB	EB	WB	NB	SB
Delay (Sec/veh)	229.7	221.8	31.9	32.5	224.9	217.1	13.7	33.2
LOS	F	F	C	C	F	F	B	C
Intersection								
Intersection Delay (Sec/veh)	199.5				194.8			
Intersection LOS	F				F			
Cycle length (Sec)	90				90			
Intersection v/c ratio	0.88				1.43			
Fuel Used (l/h)	-				740			

Intersection Six (Abu Anz 1 Intersection)

Abu Anz 1 intersection is the one of the most important intersection in the study network. It is a signalized with three legs intersection. Connecting two main districts together, Al Shmesani district with Al Rabeia district, through Al Sharif Naser Bin Jamil street Omar Bin Abdulaziz street. The intersection works in combined with Abu Anz 2. The traffic flow at this intersection will arrive to all approaches. Two approaches from Al Sharif Nasir Bin Jamel Street and the third one from Omar Bin Abdulaziz Street. U-turn is allowed in this intersection from two approaches, the first one is from NB in Al Sharif Nasir Bin Jamil street, the second U-turn is from Omer Bin Abdulaziz street. Right turn is with the through movement without separate lane at Omer Bin Abdulaziz street, But it is exclusive with separate lane at Al Sharif Nasir Bin Jamil Street to Omar Bin Abdulaziz street. The intersection signal is operated at 120 seconds cycle length with three split phases.

Table 6 shows that the intersection is operating at LOS - F with high intersection delay (231.1 sec/veh at HCS2000 and 219.8 sec/veh at Synchro-8); the degree of saturation is also high (V/C >1), the intersection is oversaturated.

Table 6: Comparison results for the existing condition of intersection 6

	HCS 2000				Synchro-8			
Approach	EB	WB	NB	SB	EB	WB	NB	SB
Delay (Sec/veh)	140.1	-	58.5	378.1	136.1	-	56.9	357.4
LOS	F	-	E	F	F	-	E	F
Intersection								
Intersection Delay (Sec/veh)	231.1				219.8			
Intersection LOS	F				F			

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Cycle length (Sec)	120	120
Intersection v/c ratio	1.43	1.75
Fuel Used (l/h)	-	1384

Intersection Seven (Abu Anz 2 Intersection)

Abu Anz 2 intersection is a signalized with four legs intersection, connecting between Al Sharif Naser Bin Jamil street with Khalil Al Kashif street from north and Rasheed Al Shartoni street from south. The intersection works in combined with Abu Anz 1.The traffic flow at this intersection will arrive to three approaches. It arrives from the both direction of Al Sharif Naser Bin Jamil street and Rasheed Al Shartoni street. U-turn is allowed in this intersection. Right turn is with the through movement without separate lane. The intersection signal is operated at 120 seconds cycle length with three split phases.

Table 7 shows that the intersection is operating at LOS E at HCS2000 and LOS - D at Synchro-8 with intersection delay (46.3 sec/veh at HCS2000 and 41.3 sec/veh at Synchro-8); the degree of saturation (V/C) is (0.93 at HCS2000 and 1.0 at Synchro-8).

Table 7 - Comparison results for the existing condition of the intersection 7

	HCS 2000				Synchro-8			
Approach	EB	WB	NB	SB	EB	NWB	NB	SB
Delay (Sec/veh)	-	75.9	43.2	45.6	-	76.2	32.0	45.9
LOS	-	E	D	D	-	E	C	D
Intersection								
Intersection Delay (Sec/veh)	46.3				41.3			
Intersection LOS	E				D			
Cycle length (Sec/veh)	120				120			
Intersection v/c ratio	0.93				1.00			
Fuel Used (l/h)	-				563			

Intersection Eight (Al Comodor Intersection)

Al Comodor intersection is the last intersection in the study network. It is a signalized with four legs intersection, connecting Al Sharif Naser Bin Jameel street with Al Sarif Abdulhameed Sharaf and Suhail Al Amere streets.

The traffic flow at Al Comodor signalized intersection will arrive to two approaches only; it arrives from the both direction of Al Sharif Nasir Bin Jamil street. There are right, through, left and U-turn movement in these approaches. The intersection traffic signal is operated at 110 second cycle lengthwithfour split phases. The flow that arrives to the other two approaches will go to right direction in separate lane with no any effect on the intersection activity.

Table 8 shows that the intersection is operating at LOS - F with high intersection delay (84.7 sec/veh at HCS2000 and 84.3 sec/veh at Synchro-8); the degree of saturation is also high (V/C >1) at both programs.

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Table 8 - Comparison results for the existing condition of the intersection 8

	HCS 2000				Synchro-8			
Approach	EB	WB	NB	SB	NEB	SWB	NB	SB
Delay (Sec/veh)	88.4	82.5	-	-	84.3	84.4	-	-
LOS	F	F	-	-	F	F	-	-
Intersection								
Intersection Delay (Sec/veh)	84.7				84.3			
Intersection LOS	F				F			
Cycle length (Sec)	110				110			
Intersection v/c ratio	1.22				1.84			
Fuel Used (l/h)	-				964			

Evaluation of Future Traffic Condition

The evaluation of the traffic volume as at year 2022 for the same signalized and geometric conditions by using HCS2000 and Synchro-8 computer programsshows that all the intersections will be working on LOS F with very high delay period.

Optimization of the Existing Traffic Network Conditions

Intersection One (Al Kindi Intersection): The detail results of using the optimization process for intersection one is shown in Appendix 1. Table 9 shows a comparison results between the existing evaluation results presented in section three and the optimization results for the year 2012. The results indicated that the total intersection delay is reduced from 101.1 sec/veh to 73.4 sec/veh, the intersection LOS is improved from LOS - F to LOS - E. the results also indicated a reduction in degree of saturation and fuel consumption.

Table 9 – Comparison results between the existing and optimization conditions for intersection 1 as in year 2012

	Existing evaluation*				Optimization condition			
Approach	EB	WB	NB	SB	EB	WB	NB	SB
Delay (Sec/veh)	37.6	-	131.7	117.5	81.1	-	52.0	90.5
LOS	D	-	F	F	F	-	D	F
Intersection								
Intersection Delay (Sec/veh)	101.1				73.4			
Intersection LOS	F				E			
Cycle length (Sec)	110				140			
Intersection v/c ratio	1.59				1.09			
Fuel Used (l/h)	956				798			

**See Table 1*

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Intersection Two (Wadi Saqra Intersection): The results show that there is no significant improvement due to the implementation of optimization process because the timing plan of this intersection was already improving by the Traffic Engineering Unit (Table 10).

Table 10 – Comparison results between the existing and optimization conditions for intersection 2 as in year 2012

	Existing evaluation*				Optimization condition			
Approach	EB	WB	NB	SB	EB	WB	NB	SB
Delay (Sec/veh)	102.7	267.1	118.4	104.7	102.7	267.1	118.4	104.7
LOS	F	F	F	F	F	F	F	F
Intersection								
Intersection Delay (Sec/veh)	147				147			
Intersection LOS	F				F			
Cycle length (Sec)	190				190			
Intersection v/c ratio	1.53				1.53			
Fuel Used (l/h)	1297				1297			

**See Table 2*

Intersection Three (Wahbah Tamari Intersection): able11 shows a comparison results between the existing evaluation results presented in chapter three and the optimization results for the year 2012. The results indicated that the total intersection delay is reduced from 184.6 sec/veh to 137.5 sec/veh, the intersection LOS is remained at LOS - F. the results also indicated a reduction in degree of saturation and fuel consumption.

Table11 – Comparison results between the existing and optimization conditions for intersection 3 as in year 2012

	Existing evaluation*				Optimization condition			
Approach	EB	WB	NB	SB	EB	WB	NB	SB
Delay (Sec/veh)	295.7	103.0	50.9	37.7	162.8	151.8	80.9	36.9
LOS	F	F	D	D	F	F	F	D
Intersection								
Intersection Delay (Sec/veh)	184.6				137.5			
Intersection LOS	F				F			
Cycle length (Sec)	135				185			
Intersection v/c ratio	1.58				1.26			
Fuel Used (l/h)	776				634			

**See Table 3*

Intersection Four (Villa Rosa Intersection): The results show that there is no significant improvement due to the implementation of optimization process because the timing plan of this intersection was already improving by the Traffic Engineering Unit (table 12)

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Table 12 – Comparison results between the existing and optimization conditions for intersection 4 as in year 2012

	Existing evaluation*				Optimization condition			
Approach	EB	WB	NB	SB	EB	WB	NB	SB
Delay (Sec/veh)	37.2	43.0	-	43.1	37.2	43.0	-	43.1
LOS	D	D	-	D	D	D	-	D
Intersection								
Intersection Delay (Sec/veh)	40.3				40.3			
Intersection LOS	D				D			
Cycle length (Sec)	110				110			
Intersection v/c ratio	1.14				1.14			
Fuel Used (l/h)	285				285			

**See Table 4*

Intersection Five (Arab Bank Intersection): Table13 shows a comparison results between the existing evaluation results presented in chapter three and the optimization results for the year 2012. The results indicated that the total intersection delay is reduced from 194.8 sec/veh to 60.6 sec/veh, the intersection LOS is improved from LOS - F to LOS - E. the results also indicated a reduction in degree of saturation and fuel consumption.

Table 13 – Comparison results between the existing and optimization conditions for intersection 5 as in year 2012

	Existing evaluation*				Optimization condition			
Approach	EB	WB	NB	SB	EB	WB	NB	SB
Delay (Sec/veh)	224.9	217.1	13.7	33.2	64.5	62.0	26.2	50.3
LOS	F	F	B	C	E	E	C	D
Intersection								
Intersection Delay (Sec/veh)	194.8				60.6			
Intersection LOS	F				E			
Cycle length (Sec)	90				110			
Intersection v/c ratio	1.43				1.05			
Fuel Used (l/h)	740				345			

**See Table 5*

Intersection Six (Abu Anz 1 Intersection)

Table14 shows a comparison results between the existing evaluation results presented in chapter three and the optimization results for the year 2012. The results indicated that the total intersection delay is reduced from 219.8 sec/veh to 175.6 sec/veh, the intersection LOS is remained at LOS - F. the results also indicated a reduction in degree of saturation and fuel consumption.

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Table14 – Comparison results between the existing and optimization conditions for intersection 6 as in year 2012

	Existing evaluation*				Optimization condition			
Approach	EB	WB	NB	SB	EB	WB	NB	SB
Delay (Sec/veh)	136.1	-	56.9	357.4	189.7	-	66.4	233.4
LOS	F	-	E	F	F	-	E	F
Intersection								
Intersection Delay (Sec/veh)	219.8				175.6			
Intersection LOS	F				F			
Cycle length (Sec)	120				200			
Intersection v/c ratio	1.75				1.42			
Fuel Used (l/h)	1384				1182			

**See Table 6*

Intersection Seven (Abu Anz 2 Intersection)

The results show that there is no significant improvement due to the implementation of optimization process because the timing plan of this intersection was already improving by the Traffic Engineering Unit (table15).

Table15 – Comparison results between the existing and optimization conditions for intersection 7 as in year 2012

	Existing evaluation*				Optimization condition			
Approach	EB	WB	NB	SB	EB	WB	NB	SB
Delay (Sec/veh)	-	76.2	32.0	45.9	-	76.2	32.0	45.9
LOS	-	E	C	D	-	E	C	D
Intersection								
Intersection Delay (Sec/veh)	41.3				41.3			
Intersection LOS	D				D			
Cycle length (Sec)	120				120			
Intersection v/c ratio	1.00				1.00			
Fuel Used (l/h)	563				563			

**See Table 7*

Intersection Eight (Al Comodor Intersection)

Table16 shows a comparison results between the existing evaluation results presented in chapter three and the optimization results for the year 2012. The results indicated that the total intersection delay is increased from 84.3 sec/veh to 85.1 sec/veh, the intersection LOS is remained at LOS - F. the results also indicated a reduction in degree of saturation with a little increase in fuel consumption.

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Table16 – Comparison results between the existing and optimization conditions for intersection 8 as in year 2012

	Existing evaluation*				Optimization condition			
Approach	NEB	SWB	NB	SB	NEB	SWB	NB	SB
Delay (Sec/veh)	84.3	84.4	-	-	83.2	86.2	-	-
LOS	F	F	-	-	F	F	-	-
Intersection								
Intersection Delay (Sec/veh)	84.3				85.1			
Intersection LOS	F				F			
Cycle length (Sec)	110				105			
Intersection v/c ratio	1.84				1.76			
Fuel Used (l/h)	964				973			

**See Table 8*

Optimization of the Future Traffic Network Conditions

Intersection One (Al Kindi Intersection): The detail results of using the optimization process for the data as in year 2022 for intersection 1 is shown in Appendix 2. Table 17 shows a comparison results between the optimization results for the year 2012 with the optimization results for the year 2022. The results indicated that the total intersection delay is increased from 73.4 sec/veh to 303.7 sec/veh, the intersection LOS is dropped from LOS - E to LOS - F. the results also indicated anincrease in degree of saturation andfuel consumption.

Table17 – Comparison results between the optimization conditions in year 2012 and year 2022 for intersection 1

	Optimization condition as in year 2012*				Optimization condition as in year 2022			
Approach	EB	WB	NB	SB	EB	WB	NB	SB
Delay (Sec/veh)	81.1	-	52.0	90.5	253.9	-	278.4	369.5
LOS	F	-	D	F	F	-	F	F
Intersection								
Intersection Delay (Sec/veh)	73.4				303.7			
Intersection LOS	E				F			
Cycle length (Sec)	140				200			
Intersection v/c ratio	1.09				1.89			
Fuel Used (l/h)	798				3356			

**See Table9*

Intersection Two (Wadi Saqra Intersection): Table 18 shows a comparison results between the optimization results for the year 2012 with the optimization results for the year 2022. The results indicated that the total intersection delay is increased from 147 sec/veh to 398.9 sec/veh, the intersection LOS is remained at LOS - F. the results also indicated an increase in degree of saturation andfuel consumption.

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Table18 – Comparison results between the optimization conditions in year 2012 and year 2022 for intersection 2

	Optimization condition as in year 2012*				Optimization condition as in year 2022			
Approach	EB	WB	NB	SB	EB	WB	NB	SB
Delay (Sec/veh)	102.7	267.1	118.4	104.7	319.4	639.3	323.9	311.5
LOS	F	F	F	F	F	F	F	F
Intersection								
Intersection Delay (Sec/veh)	147				398.9			
Intersection LOS	F				F			
Cycle length (Sec)	190				190			
Intersection v/c ratio	1.53				2.5			
Fuel Used (l/h)	1297				4274			

**See Table10*

Intersection Three (Wahbah Tamari Intersection): Table19 shows a comparison results between the optimization results for the year 2012 with the optimization results for the year 2022. The results indicated that the total intersection delay is increased from 137.5 sec/veh to 416.0 sec/veh, the intersection LOS is remained at LOS - F. the results also indicated an increase in degree of saturation andfuel consumption.

Table 19 – Comparison results between the optimization conditions in year 2012 and year 2022 for intersection 3

	Optimization condition as in year 2012*				Optimization condition as in year 2022			
Approach	EB	WB	NB	SB	EB	WB	NB	SB
Delay (Sec/veh)	162.8	151.8	80.9	36.9	546.6	408.3	161.7	84.4
LOS	F	F	F	D	F	F	F	F
Intersection								
Intersection Delay (Sec/veh)	137.5				416.0			
Intersection LOS	F				F			
Cycle length (Sec)	185				185			
Intersection v/c ratio	1.26				2.15			
Fuel Used (l/h)	634				2376			

**See Table11*

Intersection Four (Villa Rosa Intersection): Table20 shows a comparison results between the optimization results for the year 2012 with the optimization results for the year 2022. The results indicated that the total intersection delay is increased from 40.3 sec/veh to 150.2 sec/veh, the intersection LOS is dropped from LOS - D to LOS - F. the results also indicated an increase in degree of saturation andfuel consumption.

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Table20 – Comparison results between the optimization conditions in year 2012 and year 2022 for intersection 4

	Optimization condition as in year 2012*				Optimization condition as in year 2022			
Approach	EB	WB	NB	SB	EB	WB	NB	SB
Delay (Sec/veh)	37.2	43.0	-	43.1	72.3	227.2	-	196.6
LOS	D	D	-	D	E	F	-	F
Intersection								
Intersection Delay (Sec/veh)	40.3				150.2			
Intersection LOS	D				F			
Cycle length (Sec)	110				200			
Intersection v/c ratio	1.14				1.45			
Fuel Used (l/h)	285				955			

**See Table 12*

Intersection Five (Arab Bank Intersection): Table21 shows a comparison results between the optimization results for the year 2012 with the optimization results for the year 2022. The results indicated that the total intersection delay is increased from 60.6 sec/veh to 184.4 sec/veh, the intersection LOS is dropped from LOS - E to LOS - F. the results also indicated an increase in degree of saturation andfuel consumption.

Table21 – Comparison results between the optimization conditions in year 2012 and year 2022 for intersection 5

	Optimization condition as in year 2012*				Optimization condition as in year 2022			
Approach	EB	WB	NB	SB	EB	WB	NB	SB
Delay (Sec/veh)	64.5	62.0	26.2	50.3	195	184.2	181.9	140.8
LOS	E	E	C	D	F	F	F	F
Intersection								
Intersection Delay (Sec/veh)	60.6				184.4			
Intersection LOS	E				F			
Cycle length (Sec)	110				200			
Intersection v/c ratio	1.05				1.34			
Fuel Used (l/h)	345				1170			

**See Table13*

Intersection Six (Abu Anz 1 Intersection): Table 22 shows a comparison results between the optimization results for the year 2012 with the optimization results for the year 2022. The results indicated that the total intersection delay is increased from 175.6 sec/veh to 475.3 sec/veh, the intersection LOS is remained at LOS - F. the results also indicated an increase in degree of saturation andfuel consumption.

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Table22 – Comparison results between the optimization conditions in year 2012 and year 2022 for intersection 6

	Optimization condition as in year 2012*				Optimization condition as in year 2022			
Approach	EB	WB	NB	SB	EB	WB	NB	SB
Delay (Sec/veh)	189.7	-	66.4	233.4	491.9	-	166.4	650.2
LOS	F	-	E	F	F	-	F	F
Intersection								
Intersection Delay (Sec/veh)	175.6				475.3			
Intersection LOS	F				F			
Cycle length (Sec)	200				200			
Intersection v/c ratio	1.42				2.40			
Fuel Used (l/h)	1182				4172			

**See Table14*

Intersection Seven (Abu Anz 2 Intersection): Table23 shows a comparison results between the optimization results for the year 2012 with the optimization results for the year 2022. The results indicated that the total intersection delay is increased from 41.3 sec/veh to 216.4 sec/veh, the intersection LOS is dropped from LOS - D to LOS - F. the results also indicated an increase in degree of saturation andfuel consumption.

Table23 – Comparison results between the optimization conditions in year 2012 and year 2022 for intersection 7

	Optimization condition as in year 2012*				Optimization condition as in year 2022			
Approach	EB	WB	NB	SB	EB	WB	NB	SB
Delay (Sec/veh)	-	76.2	32.0	45.9	-	256.1	185.7	239.5
LOS	-	E	C	D	-	F	F	F
Intersection								
Intersection Delay (Sec/veh)	41.3				216.4			
Intersection LOS	D				F			
Cycle length (Sec)	120				200			
Intersection v/c ratio	1.00				1.46			
Fuel Used (l/h)	563				2214			

**See Table15*

Intersection Eight (Al Comodor Intersection): Table24 shows a comparison results between the optimization results for the year 2012 with the optimization results for the year 2022. The results indicated that the total intersection delay is increased from 85.1 sec/veh to 384.9 sec/veh, the intersection LOS is remained at LOS - F. the results also indicated an increase in degree of saturation andfuel consumption.

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Table24 – Comparison results between the optimization conditions in year 2012 and year 2022 for intersection 8

	Optimization condition as in year 2012*				Optimization condition as in year 2022			
Approach	NEB	SWB	NB	SB	NEB	SEB	NB	SB
Delay (Sec/veh)	83.2	86.2	-	-	336.2	413.5	-	-
LOS	F	F	-	-	F	F	-	-
Intersection								
Intersection Delay (Sec/veh)	85.1				384.9			
Intersection LOS	F				F			
Cycle length (Sec)	105				145			
Intersection v/c ratio	1.76				2.20			
Fuel Used (l/h)	973				4640			

**See Table 16*

FINDINGS

The following is the finding results drawn from the evaluation and optimization of the existing and future conditions for the study area.

Reduction in delay time and improvement of LOS at Intersection One (Al Kindi Intersection)

The intersection delay period will be decreased from 365.3 sec/veh to 303.7 sec/veh as in year 2022 when using the suggested optimization. The LOS remains at F.

Reduction in delay time and improvement of LOS at Intersection Two (Wadi Saqra Intersection)

The intersection is working on the optimization condition.

Reduction in delay time and improvement of LOS at Intersection Three (Wahbah Tamari Intersection)

The intersection delay period will be decreased from 500 sec/veh to 416 sec/veh as in year 2022 when using the suggested optimization. The LOS remains at F.

Reduction in delay time and improvement of LOS at Intersection Four (Villa Rosa Intersection)

The intersection delay period will be decreased from 172.3 sec/veh to 150.2 sec/veh as in year 2022 when using the suggested optimization. The LOS remains at F.

Reduction in delay time and improvement of LOS at Intersection Five (Arab Bank Intersection)

The intersection delay period will be decreased from 538.2 sec/veh to 184.4 sec/veh as in year 2022 when using the suggested optimization. The LOS remains at F.

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Reduction in delay time and improvement of LOS at Intersection Six (Abu Anz 1 Intersection)

The intersection delay period will be decreased from 564.0 sec/veh to 475.3 sec/veh as in year 2022 when using the suggested optimization. The LOS remains at F.

Reduction in delay time and improvement of LOS at Intersection Seven (Abu Anz 2 Intersection)

The intersection delay period will be decreased from 269.6 sec/veh to 216.4 sec/veh as in year 2022 when using the suggested optimization. The LOS remains at F.

Reduction in delay time and improvement of LOS at Intersection Eight (Al Comodor Intersection)

The intersection delay period will be increased from 383.7 sec/veh to 384.9 sec/veh as in year 2022 when using the suggested optimization. The LOS remains at F.

Improving of Degree of Saturation

Table 25 shows the degree of saturation for each intersection in different conditions. It shows that all the intersections are working on degree of saturation more than one at the existing and future conditions, which is mean that the flow volume is more than the capacity volume for all the intersections. By optimization the traffic conditions, it shows that there will be a reduction in degree of saturation but it will not be less than one.

Table 25 – Degree of saturation for each intersection in different conditions

Intersection No.	Degree of Saturation (v/c)			
	Existing condition year 2012	Future condition year 2022	Optimization condition year 2012	Optimization condition year 2022
1	1.59	2.59	1.09	1.89
2	1.53	2.5	1.53	2.5
3	1.58	2.57	1.26	2.15
4	1.14	1.85	1.14	1.45
5	1.43	2.33	1.05	1.34
6	1.75	2.84	1.42	2.40
7	1.00	1.63	1.00	1.46
8	1.84	3.00	1.76	2.20

Reduction in Fuel Consumption

Table 26 shows the fuel consumption liter/hr for all the intersections in the study area at different conditions. It shows that there will be a significant reduction in the quantity of the fuel consumption by using the suggested optimization. The study result shows that the overall reduction in fuel consumption between the future conditions at 2022 for the existing data and the optimization of the suggested conditions at 2022 will be 16%.

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Table 26 – Fuel consumption for each intersection in different conditions (l/hr)

Intersection No.	Fuel consumption (l/hr)				Percentage saving %
	Existing condition year 2012	Future condition year 2022	Optimization condition year 2012	Optimization condition year 2022	
1	956	3940	798	3356	15%
2	1297	4274	1297	4274	0%
3	776	2805	634	2376	15%
4	285	1080	285	955	12%
5	740	3313	345	1170	65%
6	1384	4867	1182	4172	14%
7	563	2630	563	2214	16%
8	964	4626	973	4640	0%
Total	6965	27535	6077	23157	16%

SUMMARY OF THE RESULTS

The final results were summarized as shown in Table 27 including the existing and optimized conditions for each intersection for the year of the time of the study at 2012 and the future conditions at year 2022.

The summary results indicate the LOS, delay period, degree of saturation and fuel consumption for each condition of each intersection of the two arterials at the selected study area in Al Shmesani district.

Table 27 – Total results Summary

Intersection No.	Condition	LOS		Delay Period *(sec/veh)*		Degree of Saturation *(v/c)*		Fuel Consumption *(l/hr)*	
		2012	2022	2012	2022	2012	2022	2012	2022
1	Existing	F	F	101.1	365.3	1.59	2.59	956	3940
	Optimized	E	F	73.4	303.7	1.09	1.89	798	3356
2	Existing	F	F	147	398.9	1.53	2.5	1297	4274
	Optimized	F	F	147	398.9	1.53	2.5	1297	4274
3	Existing	F	F	148.6	500	1.58	2.57	776	2805
	Optimized	F	F	137.5	416	1.26	2.15	634	2376
4	Existing	D	F	40.3	172.3	1.14	1.85	285	1080
	Optimized	D	F	40.3	150.2	1.14	1.45	285	955
5	Existing	F	F	194.8	538.2	1.43	2.33	740	3313
	Optimized	E	F	60.6	184.4	1.05	1.34	345	1170
6	Existing	F	F	219.8	564	1.75	2.84	1384	4867
	Optimized	F	F	175.6	475.3	1.42	2.40	1182	4172
7	Existing	D	F	41.3	269.6	1.00	1.63	563	2630
	Optimized	D	F	41.3	216.4	1.00	1.46	563	2214
8	Existing	F	F	84.3	383.7	1.84	3.00	964	4626
	Optimized	F	F	85.1	384.9	1.76	2.2	973	4640

CONCLUSIONS

1- The evaluation of the existing traffic conditions at year 2012 using Synchro-8 software shows that all the study intersections are operating at LOS F expect intersection 4 and

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intersection 7 which operating at LOS D with high delay period, degree of saturation and fuel consumption.

2- The evaluation of the future traffic conditions at year 2022 using Synchro-8 software shows that all the study intersections are operating at LOS F with high delay period, degree of saturation and fuel consumption.

3- By using updating Synchro-8 software for optimizing the existing cycle timing of the signalized intersections of the study area in year 2012 shows that intersection 4 and intersection7 will operated at LOS D. intersection 1 and intersection 5 will be operated at LOS E. and the intersections 2, 3, 6 and 8 will be operated at LOS F with high delay period, degree of saturation and fuel consumption.

4- Optimizing the future cycle timing of the signalized intersections of the study area in year 2022 shows that all the intersections will be operated at LOS F with high delay period, degree of saturation and fuel consumption.

5- The optimization of the cycle timing of the signalized intersections of the study area will reduce the delay time and the fuel consumption in very less percentage; it will not change the LOS condition of the intersections. So the modifications in the geometric conditions of the intersections are needed.

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