Evaluation and Improvement of Signalized Intersections in Amman City in Jordan

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Abstract

The main objective of this study is to evaluate and improve the traffic operations at the signalized intersections in Amman city in Jordan. Wadi-Saqra signalized intersection was chosen for this study. This intersection is located in the western central part of Amman the capital of Jordan. It has heavy traffic volume, with higher delay and heavy congestion traffic more than any other similar intersections in Amman.

In this study, the intersection is analyzed as an isolated signalized intersection by using HCM (Highway Capacity Manual) and HCS (Highway Capacity System) computer program. Synchro computer program is also used for 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 is 473 sec/veh with Level of Service F (LOS-F). Four alternatives are recommended to solve the current and future problems.

The recommended alternatives are:

1. Prohibit left turning at all approaches.
2. Optimization of the existing traffic signals.
3. Construct one through overpass for one direction.
4. Construct two overpasses or one overpass and tunnel for two directions.

The first three alternatives will not be able to reduce the level of service significantly. On the other hand, the fourth alternative will reduce the level of service from LOS F with (473 sec/veh) delay to level of service LOS C with (27 sec/veh) delay and will change the cycle length from 190 seconds to 90 seconds. The estimated initial cost of constructing two overpasses is about thirty million Jordan Dinars JD with annual saving of more than eight million JD.

If alternative four was selected to solve the existing situation the following advantages can be attained: reducing the congestion on the signalized intersection especially during peak hours, reducing the cost of traveling for the public, increasing the efficiency of the road network, increasing safety, reducing the maintenance cost of the roads, improving traffic flow and traffic operations, and reducing air pollution and preserving the environment.

Key Words: Environment, Air Pollution, Traffic Safety, Traffic Flow, Capacity, Level of Service, Signalized Intersections, Intersection Delay, Traffic Control, Intersection Design.

1. Introduction

Transportation is essential for any nation's development and growth. Transportation has played a significant role by facilitating trade, commerce, and social interaction, while consuming a considerable portion of time and resources. Many organizations and agencies exist to plan, design, build, operate, and maintain transportation systems. The movements of people and goods, which is the basis of transportation, has always been undertaken to accomplish those basic objectives or tasks that require transfer from one location to another. Every day, millions of people leave their homes and travel to a workplace, office, classroom, or distant city (Garber 2010, Abojaradeh 2013, Abojaradeh 2014).

A primary objective in highway and traffic engineering is to provide highway facilities that operate at levels of service acceptable to the users of those facilities. Regular evaluation of the level of service at the facilities will help the engineer to determine whether acceptable conditions exist and to identify those locations where improvements may be necessary (Garber 2010, Papacostas 2008).

1.1 Definition of Level of Service (LOS)

A qualitative measure, ranging from A to F that characterizes both operational conditions within a traffic stream and highway users' perception. The level of service LOS is the measure of quality of flow. The level of service is a measure of how well the facility is operating. It is both a qualitative measure of motorists' perceptions of the operational conditions existing on the facility, as well as a measure of the density of vehicular travel (Garber 2010).

Levels of different operating conditions are assigned to varying levels of service, ranging from level of service A to level of service F for each facility. The different levels of operating conditions are also related to the volume of traffic that can be accommodated by the specific component. This amount of traffic is also related to the capacity of the facility (Garber 2010). The level of service at any intersection on a highway has a significant effect on the overall operating performance of that highway. Thus, improvement of the level of service at each intersection usually results in an improvement of the overall operating performance of the highway. An analysis procedure that provides for the determination of capacity or level of service at intersections is therefore an important tool for designers, operation personnel, and policy makers. Factors that affect the level of service at intersections include the flow and distribution of traffic, the geometric characteristics, and the signalization system (Garber 2010).

1.2 Definition of Capacity

Capacity is defined as the maximum rate of flow for the subject lane group that can go through the intersection under prevailing traffic, roadway, and signalized conditions. Capacity is given in vehicles per hour (veh/h) but is based on the flow during a peak 15-minute period. Capacity analysis involves the quantitative evaluation of the capability of a road section to carry traffic, and it uses a set of procedures to determine the maximum flow of traffic that a given section of highway will carry under prevailing roadway traffic and control conditions (Garber 2010).

The aim of the study is to evaluate and improve the Wadi- Saqra at-grade isolated signalized intersection in the center of Amman city. The intersection is located in the Al-Shmesani area at the western part of Amman, the capital of Jordan, and considered as the largest intersection in Jordan in terms of the geometric conditions and traffic flow. This intersection is connecting the fifth circle with Saqra Street and Kendee Street with prince Shaker Street and Zahran Street as shown in Figure 1 from Google earth. The intersection consists of exclusive right turns, three through lanes, and two left turn lanes in each four- leg approaches (Jrew 2009).

2. Problem Definition

Wadi-Saqra signalized intersection was chosen for this study. This intersection is located in the western central part of Amman the capital of Jordan. It has heavy traffic volume, with higher delay and heavy congestion traffic more than any other similar intersections in Amman.

3. Study Objective

The main objective of this study is to evaluate and improve the traffic operations at the signalized intersections in Amman city in Jordan. Wadi-Saqra signalized intersection was chosen for this study. This intersection is located in the western central part of Amman the capital of Jordan. It has heavy traffic volume, with higher delay and heavy congestion traffic more than any other similar intersections in Amman.

4. Study Significance

If the objective of this study was achieved the following advantages can be attained: reducing the congestion on the signalized intersection especially during peak hours, reducing the cost of traveling for the public, increasing the efficiency of the road network, increasing safety, reducing the maintenance cost of the roads, improving traffic flow and traffic operations, and reducing air pollution and preserving the environment (Abojaradeh 2013, Garber 2010, Papacostas 2008).

5. Methodology

The capacity, delay and level of service (LOS) of the existing conditions were analyzed and evaluated using the Highway Capacity Manual (HCM-2010) and the Highway Capacity System (HCS) computer program. The analysis extended for the future of the next 5 years and 10 years based on 7% growth rate. Four alternatives of evaluation were also used to improve the traffic flow according to the delays, capacity and LOS for each lane group, each approach and total intersection respectively.

Synchro-6 computer program also was used for analysis, improvement, and optimization on the signalized and geometric conditions of all alternatives.

The analysis and improvement includes the following:

1. Using HCM-2010 and HCS computer program to evaluate and analysis the existing traffic signal conditions. Also, the analysis includes the traffic growth for the next 5 years and for the next 10 years.
2. Using HCS to analyze traffic signal with a prohibiting left turns movements from all approaches of the intersection. The analysis was conducted on the existing traffic signals, with constructing one over pass at N-S direction, and with constructing 2-lane two overpass on each direction of the intersection.
3. Using Synchro computer program to analyze and optimize the existing traffic signal of the intersection without changing the geometric conditions. The program also was used to optimize the traffic signal for improvement.

4. Using Synchro computer program to analyze and optimize the traffic signal with constructing 2-lane two overpasses on each direction of the intersection.

6. Related software computer programs

6.1 HCM 2010 and HCS 2010

The HCM methodology used in this analysis addresses the capacity, LOS, and other performance measures for lane groups and intersection approach and the LOS for the intersection as a whole. Capacity is evaluated in terms of the ratio of demand flow rate to capacity (v/c ratio), whereas LOS is evaluated on the basis of control delay per vehicle (in second/vehicle). Control delay is the portion of the total delay attributed to traffic signal operation for signalized intersections. Control delay includes initial delay, queue move-up time, stopped delay, and final acceleration delay. Each lane group and each approach of the intersection are analyzed separately. The methodology in this study is based on the HCM 2010 (HCM 2010).

The Highway Capacity Software (HCS 2010) implements the procedures defined in the Highway Capacity Manual (HCM 2010) for analyzing capacity and determining level of service (LOS) for Signalized Intersections, Unsignalized Intersections, Urban Streets (Arterials), Freeways, Weaving Areas, Ramp Junctions, Multilane Highways, Two-Lane Highways, and Transit. HCS 2010 is a state-of-the-art Windows application with a comprehensive Help system and the highest level of professional technical support.

6.2 Synchro-6

Synchro 6 is a complete software package for modeling and optimizing traffic signal timings. Synchro implements the intersection capacity utilization (ICU) 2003 method for determining intersection capacity, This method compares the current volume to the intersection ultimate capacity, The method is very straightforward to implement and can be determined with a single page worksheet. Synchro also implements the method of the HCS 2010 Highway Capacity Manual, chapter 15, 16, and 17; urban streets, signalized Intersection. Synchro provides an easy-to-use solution for single intersection capacity analysis and timing optimization (Synchro 2003).

6.3 Presynchro/Teapac2008

Presynchro/ Teapac 12 intersections computer program prepares input for and runs synchro-6 using the standard Teapac graphical dialogs and traffic engineering terms for each signal in the arterial or network. All the information that is needed by Synchro for each intersection is coded automatically, including the always- complex signal timing phasing information. The resulting Synchro input can also be used to run its companion Simtraffic simulation and animation. Complete networks built in Synchro can be imported into Presynchro so they can be further analyzed by other program such as Signal 2000 for HCM capacity analysis and HCM-optimization, TRANSYT-7F for time- proven network simulation and optimization, NETSUM/CORSIM and VISSIM for robust, validated simulation and animation (Presynchro/ Teapac 2008).

6.4 TRANSYT-7F

TRANSYT-7F is a traffic simulation and signal timing optimization program. The primary application of TRANSYT-7F is signal timing design and optimization.TRANYT-7F features genetic algorithm optimization of cycle length, phasing sequence, split, and offsets. TRANSYT-7F is a complete traffic signal timing optimization software package for traffic network, arterial streets, or single intersections having complex or simple conditions (TRANSYT-7F 2010).

7. Data collection

The study procedure includes data collection, which is common to the entire program. Data preparation for the traffic volumes for each approach of the intersection were collected each 15 minutes during three periods of time during the normal days. The three peak periods are from 7-9 am, 2-4 pm, and from 5-7pm at all approaches. Table-1 presents the sample of volume data and peak hour factor for the south bound direction. Table-1 shows the input worksheet required for both HCM &HCS analysis of the existing geometric, traffic, and signalized conditions. Figure 2 shows the existing peak traffic flow determined by Synchro computer program (Jrew and Abojaradeh 2012, Abojaradeh et. al. 2014).

8. HCM & HCS Output Results

Four operational analyses on the Wadi-saqra isolated signalized intersection were conducted. The analysis based on the LOS criteria for signalized intersection of HCM. The criteria are less than 10 sec/veh for LOS-A, between 10-20 sec/veh for LOS-B, between 20-35sec./veh.for LOS-C, between 35-55 sec/veh for LOS-D, between 55-80 sec/veh for LOS-E , and more than 80sec./veh. for LOS-F. The four operational analyses are:

1. Analysis of the existing condition: The analysis of the existing conditions of this study with four split phasing traffic signal and 190 sec. cycle length. indicated that the degree of saturation (v/c ratio) for all the through movements are more than one which are 1.35,1.83,1.53,and 1.76 for the EB, WB, NB, and SB respectively. The lane group LOS are E

for all left turns movements and F for all through movements. The LOS for all approaches is F and the intersection LOS is F. The final result of the intersection delay is 318.3 sec/veh as shown in table-2, table-3, and table-4. Two more analysis was conducted for the future traffic growth rate 7%. The results show an increased in total intersection delays to 587.5 sec/veh for the next 5 years and to 710 sec/veh for the next 10 years as shown in table-5.

2. Prohibiting left-turn movement: The analysis based on prohibiting left- turn movements from all approaches to allow the through movements on 5 lanes on each direction on two phases instead of four split phasing with 190 sec. cycle length. The left turn movements can be accommodated on U-Turns down stream of each direction. The results of analysis indicated an improvement on EB direction (LOS-E, and v/c=0.81). Also the total intersection delay is reduced to 102.2 sec/veh with LOS-F as shown in table-6. This analysis may produce more delays and back of queue on downstream traffic signals.

3. Constructing one overpass on N-S direction: A 2-lane overpass bridge is suggested to reduce the through traffic on the existing traffic signal to one lane with 2-lane left-turn . The results revealed that the total intersection delay is decreased to 267.8 sec/veh with LOS-F. The delay and LOS are not reduced significantly.

4. Constructing two overpass on both direction: A 2-lane overpass bridges are suggested on both direction to keep the existing traffic signal with one-lane through and two-lane left-turns in each direction and with the existing traffic signal. The results show a significant improvement on all degrees of saturation on all approaches (v/c < 1) with LOS-E. The total intersection delay is reduced to 74.5 sec/veh.

9. Synchro-6 output results

Two evaluations and two optimizations were conducted by using Senchro-6 as follows:

1. Evaluation of the existing condition: The evaluation based on the existing 190 seconds cycle length with lead-lag phasing for the N-S & E-W directions. The results indicated LOS-F for all lane groups except LOS-D for EB lane group. The results also show that LOS-F for all approaches, and the degree of saturation (v/c ratio) are 1.56, 1.83, 1.13, 1.05, and 1.74 for WBL, WBT, NBT, SBL, and SBT respectively. The total intersection delay is 473.4 sec/veh with LOS-F as shown in table-7. The analysis results show that the total intersection delays by using the Synchro program are more than the analysis results by using the HCS program.
2. Optimization the existing traffic signal: The optimization is conducted for the existing traffic cycle length with the same phasing and geometric condition. The output results of Synchro show a significant reduction on the cycle length to 140 seconds. Only EBT lane group and EB approach are improved to LOS-D and LOS-E respectively. The (v/c ratio) are improved to 0.91 on EBT and to 0.99 on WBL groups only. The EB approach is improved to LOS-E with 73.4 sec/veh approach delay. The total intersection delay is improved to become 249.6 sec/veh with LOS-F as shown in table-8. The analysis shows a limited improvements but the total intersection delays and LOS,s are not improved significantly.
3. Constructing two overpasses on both directions: The construction of 2-lane two overpass on N-S and E-W directions with the existing 190 seconds cycle length and one lane through and two lanes left-turn on each direction is analyzed by Synchro program. The results shows an improvement on LOS,s. on all approaches (LOS-D on EB approach and LOS-E on the other approaches),and the total intersection delay reduced to 55.2 sec/veh with LOS-E. The analysis is not showing a significant improvement with the existing traffic signal conditions.
4. Constructing two overpass on both direction with optimization of the cycle length: Synchro is used to optimize the cycle length with lead-lag phasing on the intersection of one lane through and 2-left turn lanes in all directions and with 2-lane two overpasses on N-S and E-W directions. The results shows a very significant solution to improve the intersection traffic flow. The cycle length is reduced to 90 seconds and the EB approach is improved to LOS-A, and the other approaches are improved to LOS-C. The total intersection delay is reduce to 27 sec/veh with LOS-C.

10. Preliminary Cost Analysis

According to the previous traffic flow analysis and improvement conducted on the Wadi- saqra signalized intersection. The following calculation is suggested as a preliminary benefit / cost analysis study based on information from the experts at Greater Amman Municipality and from the contractors.

The following two assumptions are used in the analysis:

1. The cost of two 2-lane overpass bridges = 30000000 JD
2. the min. salary for Jordanian citizen = 1.5 JD per Hour

The following is the benefit- cost analysis:

- The average total intersection delay for the existing condition = 473 sec/veh for the 190 seconds cycle length
- The final total intersection delay after constructing the two overpasses = 27 sec/veh for 90 seconds cycle length.
- Delay saving = 473-27= 446 sec/veh for each existing cycle length.
- No. of existing cycles per hour = 18.94
- Total delay /hour = 18.947*446= 8450.362 sec/hr.
- Total Delay for peak hourly volume on all approaches = 9145*8450.362 = 77.278560E6 seconds = 21466 hours.
- Total saving per one day = 21466 hrs *1.5 JD/hr. = 32199 JD

- Weekly vacation = 2 days
- Yearly saving = 5/7 * 360 * 32199 = 8371740 JD
- Benefit for the next 20 years = 167434800 JD
- Initial cost of constructing two overpass 2-lane bridges = 30000000 JD
- Therefore the B/C ratio = 167434800/30000000= 5.58

The analysis shows that B/C ratio is more than one which indicate a cost effectiveness to build the two overpasses with a traffic signal of 90 sec. cycle length.

11. Summary and Conclusions

The HCM, HCS, and Synchro computer programs were produced a very interesting results for analyzing, improvement and optimize the isolated signalized Wadi- Saqra intersection. The alternative analysis on all the programs show that the LOS and the degree of saturation for all approaches and for whole intersection can not be improved without constructing an overpass bridges for 2/3 of through traffic flow in each direction and with a combination of traffic signal of 90 sec. cycle length for 1/3 of through traffic volumes and 2-lane left turn volume movements on each direction of the intersection. The final analysis by Synchro shows a very significant reduction on total intersection delays and LOS. The total delay reduced from 473.4 sec/veh to 27 sec/veh which mean that this particular intersection must be changed in geometric design to include the two overpasses from N-S and from E-W directions. Other geometric design such a full or partial cloverleaf interchange or diamond interchange can not be constructed because there are not enough spaces or right of ways to build these geometric design alternatives.

The preliminary cost analysis shows that the benefits of constructing the two overpasses are 5.6 times the initial cost. The analysis was conducted without considering the growth of the traffic volume for the next 5 years or for the next 10 years as shown in table-5. Considering the growth of traffic volume may increase the calculated benefits, therefore more research is needed to determine the cost effectiveness.

If the two overpasses were constructed to solve the existing situation the following advantages can be attained: reducing the congestion on the signalized intersection especially during peak hours, reducing the cost of traveling for the public, increasing the efficiency of the road network, increasing safety, reducing the maintenance cost of the roads, improving traffic flow and traffic operations, and reducing air pollution and preserving the environment.

12. Recommendations

Based upon the results and findings, the following recommendations are drawn:

1. The HCS computer program is a very good software to analyze an isolated intersections such as Wadi-Saqra intersection based on HCM-2000 without optimization of the traffic signals, therefore, it is recommended to use updated software SIGNAL2000/TEAPAC capacity that implements the capacity analysis techniques of the HCM-2000 only as level-1analysis and adding level-2 analysis which includes an optimization option that produces the best possible capacity analysis for the given conditions.
2. The Synchro computer program was used to analyze and optimize the Wadi-Saqra isolated intersection without any combination with the HCS computer program, therefore, it is recommended to use the Presynchro/Teapac software which includes a combination of analysis and optimization of Synchro program with Signal-2000 program for true-HCM capacity analysis and HCM-optimization.
3. The Wadi-Saqra was analyzed as an isolated intersection at the middle of network signalized intersections at Al-Shmesani area, Therefore, it is recommended to use TRANSYT-7F computer program for simulation, optimization, and coordination of all the signalized intersections at the network system in Al-Shmesania area.
4. Progression with actuated controllers are recommended to help traffic engineers in applying signal timing programs to actual control equipment . It provides guide lines for TRANSYT-7F.
5. Constructing of overpass , tunnels, or trumpet interchanges at some intersections in Al-Shmesani area with a combination of a traffic signals are recommended to reduce stops, delay and fuel consumption on the long term planning.
6. More research is needed for economic evaluation including the network traffic signal at Al-Shmesani area with the consideration of the growth in the traffic flow for next 5 years, 10 years and 20 years.

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REFERNCES

Abojaradeh M., and Jrew B., (2014).“The Effect of Driver Behavior Mistakes on Traffic Safety". Journal of Civil and Environment Research issued from IISTE USA. Volume 6, No. 1, 2014. pp 39-54.

Abojaradeh, M., Abu-Khurma M., Msallam M., and Jrew B., (2014). "Evaluation and Improvement of Traffic Flow of Signalized Intersections on Part of Zarqa Expressway in Zarqa City in Jordan". published and presented in The Fourth Jordan International Conference and Exhibition for Roads and Transport: "High Priority Issues in the Future Transport Sector", 12-13/03/2014 Amman, Jordan.

Abojaradeh M., and Jrew B., (2013). "Development of Statistical Prediction Models to Reduce Fatal and Injury Traffic Accidents". Journal of Environment and Earth Science issued from IISTE USA. Volume 3, No. 11, 2013. pp 54-65.

Abojaradeh, M., Jrew B., and A. Abojaradeh, (2012). "The Effect of Driver Behavior Mistakes on Traffic Safety in Jordan" published and presented in the 6th Traffic Safety in Jordan by the Jordan Traffic Institute, Jordan 19-20 November 2012.

Abojaradeh M., (2013), "Evaluation of Pedestrian Bridges and Pedestrian Safety in Jordan" Journal of Civil and Environment Research issued from IISTE USA. Volume 3, No. 1, 2013. pp 66-78.

Abojaradeh M., (2013), "Traffic Accidents Prediction Models to Improve Traffic Safety in Greater Amman Area". Journal of Civil and Environment Research issued from IISTE USA. Volume 3, No. 2, 2013. pp 87-101.

Abojaradeh M., (2013), "Travel Time and Delay Study to Improve Public Transit Systems in Jordan". (2013) Journal of Environment and Earth Science issued from IISTE USA. Volume 3, No. 4, 2013. pp 85-97.

Garber, N.J., Hoel, L.A. (2010), Traffic and Highway Engineering, 4th SI Edition, USA.

Highway Administration FHWA (2010), the Highway Safety Improvement Program (HSIP), USA.

Highway Capacity Manual HCM (2010), Transportation Research Board's (TRB) fifth edition of the Highway Capacity Manual HCM, Washington D.C. USA 2010.

Jrew B., and Abojaradeh M., (2009). "Evaluation and Improvement of Wadi-Saqra Signalized Intersection in Amman City". The Forth Conference in Scientific Research in Jordan, Jordan Society for Scientific Research, 7 November 2009, Amman Jordan. Highway and Traffic in Jordan, pp 3-19.

Jrew B., Abojaradeh M., and E. Abojaradeh, (2012). "Development of Statistical Prediction Models to reduce Fatal and Injury Accidents in Jordan" published and presented in the 6th Traffic Safety in Jordan by the Jordan Traffic Institute, Jordan 19-20 November 2012.

Papacostas C., Prevedonros P. (2008), Transportation Engineering and Planning, Fourth Edition, USA.

PreSynchro/ Teapac (2008), McTrans for Microcomputer in Transportation, University of Florida, USA 2008

Synchro- user guide (2003), written by David Husch, and John Albeck, Trafficware, USA 2003

TRANSYT-7F User- Manual (2010), FHWA, U.S Department of Transportation, USA 2010

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Figure 1: Wadi-Saqra Intersection Layout from Google Earth

Table 1: Sample of Traffic Volume Data for South Bound Direction

Time	*Left Turn*	*Through*	*Total*	*Volume*					*Peak Hour Factor*				
07:00 – 07:15	109	180	289	1594					0.76				
07:15 – 07:30	139	237	375		1787					0.85			
07:30 – 07:45	136	347	483			2154					0.94		
07:45 – 08:00	173	394	567				1969					0.93	
08:00 – 08:15	141	408	549					1980					0.93
08:15 – 08:30	128	427	555										
08:30 – 08:45	107	337	445										
08:45 – 09:00	99	408	507										
14:00 – 14:15	104	239	343	1895					0.88				
14:15 – 14:30	153	388	541		2065					0.95			
14:30 – 14:45	170	354	524			2038					0.97		
14:45 – 15:00	145	342	487				2021					0.98	
15:00 – 15:15	127	386	513					1922					0.93
15:15 – 15:30	116	398	514										
15:30 – 15:45	136	371	507										
15:45 – 16:00	104	284	388										
17:00 – 17:15	138	326	463	1850					0.92				
17:15 – 17:30	122	322	444		1879					0.94			
17:30 – 17:45	111	331	442			1933					0.96		
17:45 – 18:00	137	365	501				1966					0.98	
18:00 – 18:15	148	344	492					1922					0.96
18:15 – 18:30	138	360	498										
18:30 – 18:45	135	341	475										
18:45 – 19:00	150	307	457										

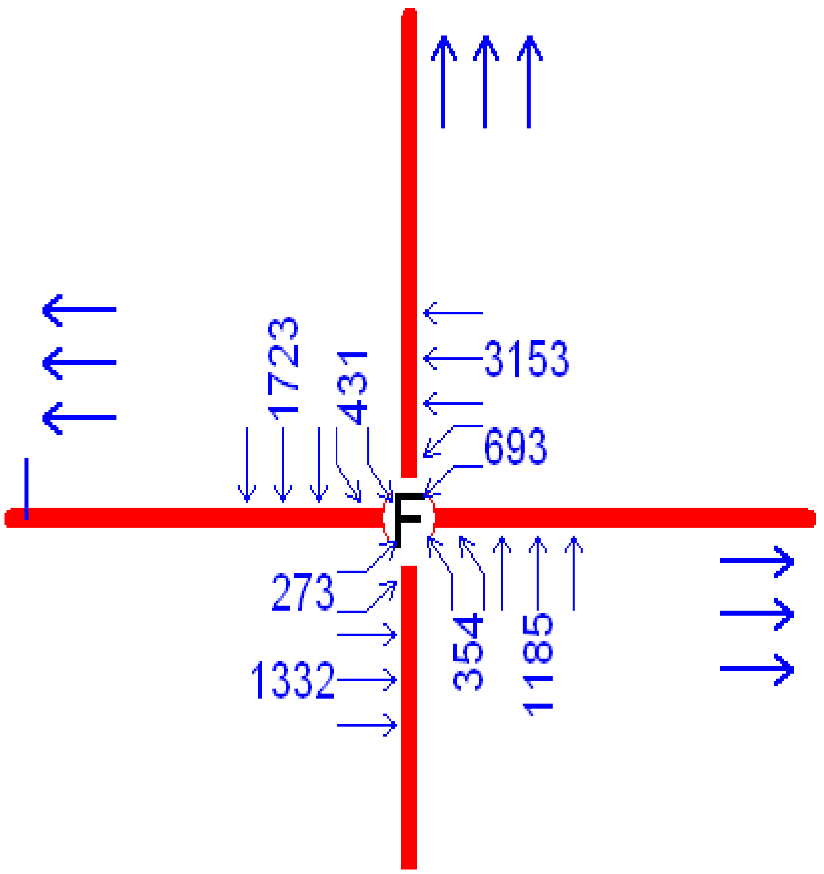

Figure 2: Existing Peak Traffic Flow as Shown by Synchro

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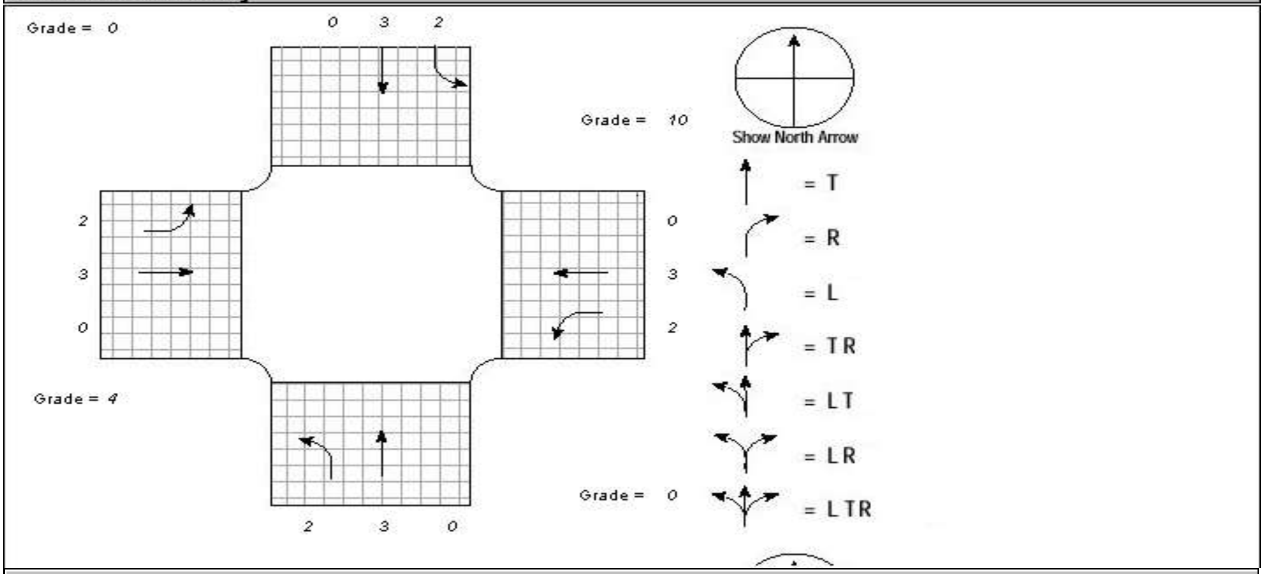
Table 2: Input Worksheet for HCM & HCS

INPUT WORKSHEET

General Information		Site Information	
Analyst	*khaled joudeh & malek jaber*	Intersection	*wadi saqra*
Agency or Co.	*Alisra University*	Area Type	*All other areas*
Date Performed	*11/05/1429*	Jurisdiction	
Time Period	*7.30-8.30*	Analysis Year	*2008*

Intersection Geometry



Volume and Timing Input

	EB			WB			NB			SB		
	LT	TH	RT	LT	TH	RT	LT	TH	RT	LT	TH	RT
Volume (vph)	273	1332		693	3153		354	1185		431	1723	
% Heavy veh	0	0		0	0		0	0		0	0	
PHF	0.84	0.84		0.93	0.93		0.86	0.86		0.93	0.93	
Actuated (P/A)	P	P		P	P		P	P		P	P	
Startup lost time	2.0	2.0		2.0	2.0		2.0	2.0		2.0	2.0	
Ext. eff. green	2.0	2.0		2.0	2.0		2.0	2.0		2.0	2.0	
Arrival type	3	3		3	3		3	3		3	3	
Ped volume		0			0			0			0	
Bicycle volume												
Parking (Y or N)	N		N	N		N	N		N	N		N
Parking/hr												
Bus stops/hr	0	0		0	0		0	0		0	0	
Ped timing		0.0			0.0			3.0			0.0	

	EB Only	WB Only	03	04	SB Only	NB Only	07	08
Timing	G = 40.0	G = 65.0	G =	G =	G = 35.0	G = 30.0	G =	G =
	Y = 3.0	Y = 3.0	Y =	Y =	Y = 3.0	Y = 3.0	Y =	Y =
Duration of Analysis (hrs) = 0.25					Cycle Length C = 190.0			

HCS2000™ Version 4.1

Table 3: The Volume Adjustment and Saturation Flow Rate for HCM&HCS

VOLUME ADJUSTMENT AND SATURATION FLOW RATE WORKSHEET												
General Information												
Project Description	*anlysis of wadi saqra intersection*											
Volume Adjustment												
	EB			WB			NB			SB		
	LT	TH	RT	LT	TH	RT	LT	TH	RT	LT	TH	RT
Volume	273	1332		693	3153		354	1185		431	1723	
PHF	0.84	0.84		0.93	0.93		0.86	0.86		0.93	0.93	
Adj. Flow Rate	325	1586		745	3390		412	1378		463	1853	
Lane Group	L	T		L	T		L	T		L	T	
Adj. flow rate	325	1586		745	3390		412	1378		463	1853	
Prop. LT or RT		--			--	0.000		--	0.000		--	0.000
Saturation Flow Rate												
Base satflow	1900	1900		1900	1900		1900	1900		1900	1900	
Num. of lanes	2	3	0	2	3	0	2	3	0	2	3	0
fW	1.000	1.000		1.000	1.000		1.000	1.000		1.000	1.000	
fHV	1.000	1.000		1.000	1.000		1.000	1.000		1.000	1.000	
fg	0.980			0.950			1.000			1.000		
fp	1.000	1.000		1.000	1.000		1.000	1.000		1.000	1.000	
fbb	1.000	1.000		1.000	1.000		1.000	1.000		1.000	1.000	
fa	1.00			1.00			1.00			1.00		
fLU	1.00	1.00		1.00	1.00		1.00	1.00		1.00	1.00	
fLT	0.950	1.000	--	0.950	1.000	--	0.950	1.000	--	0.950	1.000	--
Secondary fLT			--			--			--			--
fRT	--	1.000		--	1.000		--	1.000		--	1.000	
fLpb	1.000	1.000	--	1.000	1.000	--	1.000	1.000	--	1.000	1.000	--
fRpb	--	1.000		--	1.000		--	1.000		--	1.000	
Adj. satflow	3538	5586		3429	5415		3610	5700		3610	5700	
Sec. adj. satflow			--			--			--			--

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Table 4: The Capacity and LOS Output from HCM&HCS for the Existing Situation

CAPACITY AND LOS WORKSHEET

General Information

Project Description *anlysis of wadi saqra intersection*

Capacity Analysis

	EB			WB			NB			SB		
Lane group	*L*	*T*		*L*	*T*		*L*	*T*		*L*	*T*	
Adj. flow rate	*325*	*1586*		*745*	*3390*		*412*	*1378*		*463*	*1853*	
Satflow rate	*3538*	*5586*		*3429*	*5415*		*3610*	*5700*		*3610*	*5700*	
Lost time	*2.0*	*2.0*		*2.0*	*2.0*		*2.0*	*2.0*		*2.0*	*2.0*	
Green ratio	*0.21*	*0.21*		*0.34*	*0.34*		*0.16*	*0.16*		*0.18*	*0.18*	
Lane group cap.	*745*	*1176*		*1173*	*1853*		*570*	*900*		*665*	*1050*	
v/c ratio	*0.44*	*1.35*		*0.64*	*1.83*		*0.72*	*1.53*		*0.70*	*1.76*	
Flow ratio	*0.09*	*0.28*		*0.22*	*0.63*		*0.11*	*0.24*		*0.13*	*0.33*	
Crit. lane group	*N*	*Y*		*N*	*Y*		*N*	*Y*		*N*	*Y*	
Sum flow ratios	*1.48*											
Lost time/cycle	*20.00*											
Critical v/c ratio	*1.65*											

Lane Group Capacity, Control Delay, and LOS Determination

	EB			WB			NB			SB		
Lane group	*L*	*T*		*L*	*T*		*L*	*T*		*L*	*T*	
Adj. flow rate	*325*	*1586*		*745*	*3390*		*412*	*1378*		*463*	*1853*	
Lane group cap.	*745*	*1176*		*1173*	*1853*		*570*	*900*		*665*	*1050*	
v/c ratio	*0.44*	*1.35*		*0.64*	*1.83*		*0.72*	*1.53*		*0.70*	*1.76*	
Green ratio	*0.21*	*0.21*		*0.34*	*0.34*		*0.16*	*0.16*		*0.18*	*0.18*	
Unif. delay d1	*65.2*	*75.0*		*52.5*	*62.5*		*76.0*	*80.0*		*72.5*	*77.5*	
Delay factor k	*0.50*	*0.50*		*0.50*	*0.50*		*0.50*	*0.50*		*0.50*	*0.50*	
Increm. delay d2	*1.9*	*162.6*		*2.6*	*375.4*		*7.8*	*244.6*		*5.9*	*348.1*	
PF factor	*1.000*	*1.000*		*1.000*	*1.000*		*1.000*	*1.000*		*1.000*	*1.000*	
Control delay	*67.1*	*237.6*		*55.2*	*437.9*		*83.8*	*324.6*		*78.5*	*425.6*	
Lane group LOS	*E*	*F*		*E*	*F*		*F*	*F*		*E*	*F*	
Apprch. delay	*208.6*			*368.9*			*269.2*			*356.2*		
Approach LOS	*F*			*F*			*F*			*F*		
Intersec. delay	*318.3*			Intersection LOS						*F*		

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Table 5: Total Intersection Delays for the Next 5 and 10 Years

	Present situation	Situation after 5 years	Situation after 10 years
Total intersection delay	**318 sec/veh.**	**587.5 sec/veh.**	**710 sec/veh.**
LOS	**F**	**F**	**F**

Table 6: Sample Output of HCS for Through Movement Only With Prohibiting the Left-Turns Movements

HCS2000: Signalized Intersections Release 4.1

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								
T	1960	9310	0.81	0.21	75.1	E	75.1	E
Westbound								
T	3088	9025	1.10	0.34	112.3	F	112.3	F
Northbound								
T	1500	9500	0.92	0.16	89.3	F	89.3	F
Southbound								
T	1750	9500	1.06	0.18	116.5	F	116.5	F

Intersection Delay = 102.2 (sec/veh)   Intersection LOS = F

Table 7: The Analysis Results by Synchro for the Existing Traffic Signal Conditions

Timings
1: E/W St. & N/S St. 1/1/2002

Lane Group	EBL	EBT	WBL	WBT	NBL	NBT	SBL	SBT
Lane Configurations								
Volume (vph)	273	1332	693	3153	354	1185	431	1723
Turn Type	Prot		Prot		Prot		Prot	
Protected Phases	5	2	1	6	3	8	7	4
Permitted Phases								
Detector Phases	5	2	1	6	3	8	7	4
Minimum Initial (s)	4.0	10.0	4.0	10.0	4.0	10.0	4.0	10.0
Minimum Split (s)	11.0	23.0	11.0	22.5	11.0	32.0	11.0	32.0
Total Split (s)	45.0	87.0	28.0	70.0	34.0	49.0	26.0	41.0
Total Split (%)	23.7%	45.8%	14.7%	36.8%	17.9%	25.8%	13.7%	21.6%
Yellow Time (s)	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
All-Red Time (s)	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
Lead/Lag	Lead	Lag	Lead	Lag	Lead	Lag	Lead	Lag
Lead-Lag Optimize?								
Recall Mode	Max	Max	Max	Max	Max	Max	Max	Max
Act Effct Green (s)	42.9	84.9	26.0	68.0	31.9	46.9	23.9	39.0
Actuated g/C Ratio	0.23	0.45	0.14	0.36	0.17	0.25	0.13	0.21
v/c Ratio	0.42	0.70	1.56	1.83	0.74	1.13	1.05	1.74
Uniform Delay, d1	62.8	42.2	82.0	61.0	75.0	71.5	83.0	75.5
Control Delay	64.8	44.2	307.7	407.2	83.8	131.3	132.3	376.5
Queue Delay	674.5	0.0	422.0	302.4	672.4	0.0	638.0	0.0
Total Delay	739.3	44.2	729.7	709.6	756.1	131.3	770.3	376.5
LOS	F	D	F	F	F	F	F	F
Approach Delay		162.4		713.2		275.1		455.2
Approach LOS		F		F		F		F

Intersection Summary	
Cycle Length: 190	
Actuated Cycle Length: 190	
Offset: 0 (0%), Referenced to phase 2:EBT and 6:WBT, Start of Green	
Natural Cycle: 150	
Control Type: Pretimed	
Maximum v/c Ratio: 1.83	
Intersection Signal Delay: 473.4	Intersection LOS: F
Intersection Capacity Utilization 125.4%	ICU Level of Service H
Analysis Period (min) 15	

Table-8 Optimization by Synchro of the Existing Traffic Signal Conditions

Timings
1: E/W St. & N/S St. 1/1/2002

Lane Group	EBL	EBT	WBL	WBT	NBL	NBT	SBL	SBT
Lane Configurations								
Volume (vph)	273	1332	693	3153	354	1185	431	1723
Turn Type	Prot		Prot		Prot		Prot	
Protected Phases	5	2	1	6	3	8	7	4
Permitted Phases								
Detector Phases	5	2	1	6	3	8	7	4
Minimum Initial (s)	4.0	10.0	4.0	10.0	4.0	10.0	4.0	10.0
Minimum Split (s)	11.5	23.0	11.0	23.5	11.0	32.0	11.0	32.0
Total Split (s)	13.0	50.0	32.0	69.0	15.0	39.0	19.0	43.0
Total Split (%)	9.3%	35.7%	22.9%	49.3%	10.7%	27.9%	13.6%	30.7%
Yellow Time (s)	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
All-Red Time (s)	3.0	2.0	2.0	3.0	2.0	3.0	3.0	3.0
Lead/Lag	Lead	Lag	Lead	Lag	Lead	Lag	Lead	Lag
Lead-Lag Optimize?								
Recall Mode	Max	Max	Max	Max	Max	Max	Max	Max
Act Effct Green (s)	11.1	48.0	30.0	67.1	13.0	37.0	16.9	41.0
Actuated g/C Ratio	0.08	0.34	0.21	0.48	0.09	0.26	0.12	0.29
v/c Ratio	1.20	0.91	0.99	1.37	1.33	1.06	1.09	1.22
Uniform Delay, d1	64.5	43.9	54.9	36.5	63.5	51.5	61.5	49.5
Control Delay	174.1	52.7	85.8	198.6	217.4	90.8	125.8	147.2
Queue Delay	0.0	0.0	658.5	35.0	518.3	0.0	622.8	0.0
Total Delay	174.1	52.7	744.3	233.6	735.7	90.8	748.7	147.2
LOS	F	D	F	F	F	F	F	F
Approach Delay		73.4		325.6		239.3		267.5
Approach LOS		E		F		F		F

Intersection Summary

Cycle Length: 140
Actuated Cycle Length: 140
Offset: 0 (0%), Referenced to phase 2:EBT and 6:WBT, Start of Green
Natural Cycle: 140
Control Type: Pretimed
Maximum v/c Ratio: 1.37
Intersection Signal Delay: 249.6 Intersection LOS: F
Intersection Capacity Utilization 125.4% ICU Level of Service H
Analysis Period (min) 15

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