The Effect of Traffic Volumes, Percentage of Heavy Vehicles and Driver Behavior on the Performance of Signalized Intersections

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Abstract

Presented in this paper is measuring the effect of traffic volumes, percentage of heavy vehicles and driver behavior on the signalized intersections performance. For the signalized intersections, there are several traffic variables affecting the level of service. In general, there are three main categories of variables: the traffic volume and traffic volume forecast, driver behavior, and the type or the quality of the forecasting model itself.

This paper focusing on the effect of the input data and parameters has on the output results which are often considered in highway capacity analysis. Typically, analyst produce a single number that represents the performance of the facility, with no statement refer to a likely range of variation in the result.

It is the responsibility of the analyst to measure and report the effect of traffic variables with his or her estimate of level of service and how it will affect the problem or decision under consideration. The purpose of this paper is to consider which variables have a significant effect on the level of service for signalized intersections.

The results of the paper showed that; among all traffic variables, traffic volume and driver behavior are the variables that have the more effect on the signalized intersection performance (i.e. it is affect to any changes in these two variables).

1- Introduction:

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 [1].

The procedures for determining the Level of Service (LOS) at an intersection can be used for either a detailed or operational evaluation of a given intersection or a general planning estimate of the overall performance of an existing or planned signalized intersection [1].

The primary purpose in applying the procedures of the Highway Capacity Manual (HCM) is to produce information that is useful in making a decision about a transportation facility or system [2]. The various HCM procedures produce forecasts of one or more performance measures, one of which is tied to a level of service grade.

The nature of the decision under consideration helps to identify one of the three analytical procedures most appropriate for use for a given problem: operational analysis, design analysis, or planning analysis.

An operational analysis is used to identify a potential problem in a given facility or system and how it might be remedied [2]. The HCM 2000 notes that [3]: "… decisions that can be made, using the results from the HCM, include a choice among alternative intersection controls, a choice among alternative signal phasing and timing arrangements, a choice among alternative minor changes to control and marking … , and a choice among a combination of actions."

The HCM 2000 notes the importance of the role of sensitivity analysis [3]:

"Once one or more performance measures have been selected for use in reporting analysis results, decision making can be improved by showing how the numerical values (or the letter grade for LOS) change when one or more of the assumed input values changes. For the decision maker, it may be quite important to know how an assumed increase of 15 percent in future traffic volume (compared with the standard forecast volume) will affect delay and level of service at a signalized intersection. By providing a central value along with values based on upward and downward assumptions on key input variables (especially volume), the analyst can ensure that decision-making is based on a full understanding of sensitivities."

The HCM 2000 includes a discussion of the quality of the results as they relate to the quality of the input variables [3]:

"The analyst should recognize that the quality of the results is dependent on the quality of the input data. Default values will produce less accurate results than field measured data. Generic default values suggested in this manual will produce less accurate results than locally developed default values."

In general, the traffic variables affect our results in three ways:

1. The input data that is propagated through to the final results and calculation.
2. The nature or quality of the forecasting model itself that again effect in the results.
3. The driver behavior.

This paper presents a measuring of the effect of traffic variable (input data) on the results of the capacity analysis for the signalized intersections.

2- Objectives of the Study:

The main objectives of the present study are:

1. Evaluation of traffic performance operation in two congested signalized intersections in Kalar City. This can be achieved by the estimation of the existing LOS at the study area.
2. Measuring the effect of changing in the traffic variables (traffic volumes, percentage of heavy vehicles and driver behavior) on the signalized intersection performance

3- Study Area:

Kalar city is the center of Kalar District located in northeast of Iraq lies on Sirwan (Diyala) river, and it is one of Sulaimaniya Governorate Districts. Currently Kalar city is the center of Garmian Area Administration, the population of Kalar City is (197,230 persons) which represent (74%) of Kalar District population.

Kalar now is in a continuous progression toward further urban expansion, infrastructural growth and economic booming, due to its location which connects Iraq, Iran and Kurdistan together, Kalar can be considered as one of the most expensive place in the entire region, economists have classified Kalar's properties as more expensive than many other advanced countries including USA. The rapid increase of Kalar City population is the main cause of the increasing demand for transportation and mobility. This may create major operation problems especially during the peak periods.

In order to:

1. Measure the effect of the traffic variables (traffic volumes, percentage of heavy vehicles and driver behavior) on the signalized intersections performance.
2. Minimize and eliminate current and future operation problems in Kalar City traffic system.

Shahid Hama Rash and SheraiNaqib intersections are selected. Both locations have congested traffic and represent significant traffic facilities in Kalar City traffic system due to the following reasons:

1. Shahid Hama Rash intersection is located on a very important commercial route that connects three governorates; Diyala, Sulaimaniya and Salah Al-Din in addition to two official border points with Iran.
2. SheraiNaqib intersection is located in center of Kalar in center of number of very important government facilities and departments such as; SheraiNaqib Maternity Governmental Hospital, Saya Private Hospital and Passports Department.

4- Analysis of Signalized Intersections:

The procedures presented here for the operational evaluation are those given in the 2000 edition of the *Highway Capacity Manual*. These procedures deal with the computation of the level of service at the intersection approaches and the level of service at the intersection as a whole.

Control delay is used to define the level of service at signalized intersections since delay not only indicates the amount of lost travel time and fuel consumption but it is also a measure of the frustration and discomfort of motorists. Control or signal delay, which is that portion of total delay that is attributed to the control facility, is computed to define the level of service at the signalized intersection. This includes the delay due to the initial deceleration, queue move up time, stopped time, and final acceleration. Delay, however, depends on the red time, which in turn depends on the length of the cycle. Reasonable levels of service can therefore be obtained for short cycle lengths, even though the (v/c) ratio is as high as 0.9. To the extent that signal coordination reduces delay, different levels of service may also be obtained for the same (v/c) ratio when the effect of signal coordination changes [1].

Delay is represented by "the additional travel time experienced by a driver, passenger, or pedestrian". The HCM provides equations for calculating control delay, the delay a motorist experiences that is attributable to the presence of the traffic signal and conflicting traffic. This includes time spent decelerating, in queue, and accelerating. The control delay equation comprises three elements: uniform delay, incremental delay, and initial queue delay. The primary factors that affect control delay are lane group volume, lane group capacity, cycle length, and effective green time. Factors are provided that account for various conditions and elements, including signal controller type, upstream metering, and delay and queue effects from oversaturated conditions [2].

The average control delay per vehicle in HCM2000 is:

$$d = d_1 f_p + d_2 + d_3 \qquad \text{--------------- (1)}$$

where:
d_1: is uniform control delay ($d_1 \cong d_u$),
f_p: is uniform delay progression adjustment factor,
d_2: is incremental delay, and
d_3: is initial queue delay, which estimates the additional delay due to an initial queue at the beginning of an analysis period.

The incremental delay is:

$$d_2 = 900T\,(X-1+((X-1)^2+8KIX/cT)^{0.5}) \qquad \text{--------------- (2)}$$

where:
T: is the length of the analysis period (hours),
k: is the incremental delay factor that is dependent on controller settings, and
I: is the upstream filtering/metering adjustment factor.

The model is adjusted for traffic-actuated control with factor k depending on unit extension and degree of saturation. For isolated pretimed signals $k = 0.5$ and $I = 1.0$. Control delay is used as the basis for determining LOS [4].

Figure (1) shows the input and the computation order for the method. The primary output of the method is the level of service (LOS).

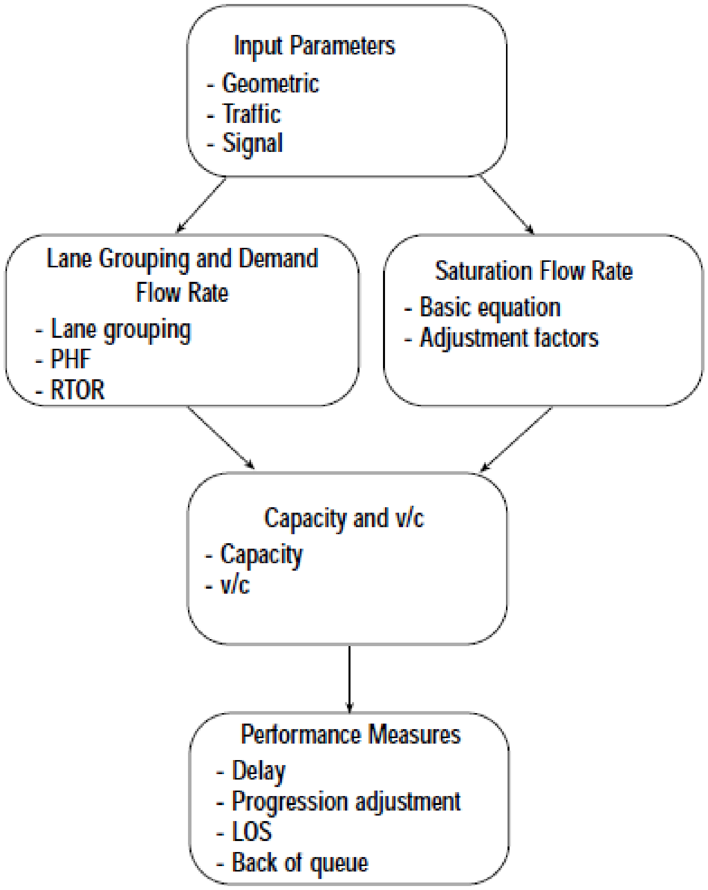

Figure (1) Signalized intersection methodology [2]

The LOS criteria for signalized intersection in HCM2000 is:

The average control delay per vehicle is estimated for each lane group and aggregated for each approach and for the intersection as a whole. LOS is directly related to the control delay value. The criteria are listed in the Table (1).

Table (1) LOS Criteria for signalized intersections

LOS	Control Delay per Vehicle (s/veh)
A	≤10
B	>10-20
C	>20-35
D	>35-55
E	>55-80
F	> 80

The Highway Capacity Manual defines quality of service as how well a transportation facility operates from the perspective of the users of that facility. Level of service is a "quantitative stratification of a performance measure that represents the quality of service." For a signalized intersection, average delay is used as the performance measure. The HCM provides level of service ranges for a signalized intersection as shown in Table (1). These ranges can be applied to an intersection approach or to the entire intersection. It should be noted that if the 250 veh/hr volume-to-capacity ratio exceeds one, the level of service will be F, regardless of the estimated delay [5].

Several guides including the Highway Capacity Manual as well as various software packages based on these guides, have defined measures to assign letter grades. In past editions, Canadian Capacity Guide for Signalized Intersections made reference to assigning letter grades to qualitatively measure the intersection operational conditions based on the old HCM average stopped delay. It is noted that the HCM 2000 now bases Level of Service on control delay. However, it is believed that there is more logic in basing the Level of Service primarily on the volume to capacity ratio (degree of saturation) [6].

Table (2) describes the ranges of V/C ratio that define each level, and the characteristics of each level [6].

The table also lists the current HCM thresholds for Level of Service (based on control delay). A delay-based Level of Service can produce very conservative results. A small number of vehicles turning from a minor street may have a disproportionate impact on Level of Service because of the high delay. There needs to be consideration in the method for the range of typical operating conditions at signalized intersections [6].

The nomenclature in Table (2) originated from the recommendations in the 1965 Highway Capacity Manual. The delay per vehicle threshold tends to address driver discomfort and fuel consumption for the time lost at an intersection due to deceleration, stopping and acceleration. Delay is considered to be a subjective entity that can vary for different individuals, situations and locations. A relationship between the driver discomfort and delay may not be linear. It should also be noted that the delay is also a time specific parameter. A delay acceptable under today's increasing congestion may not have been acceptable in the past when there were fewer vehicles on the road. A similar trend is expected in the future. In comparison, a ratio of discharging volume to capacity, in most conditions, represent the traffic utilization of the available roadway capacity. Compared to delay, a V/C value is discreet and definitive, and gives a clearer picture of the amount of available capacity remaining in an intersection independent of the time, user, location etc. [6].

This Guide, basing Level of Service on V/C, presents an accurate representation of the operation of the intersection. The V/C is a fixed quantity that speaks to a logical assessment of the relationship between traffic volumes and approach capacity [6].

Table (2) Levels of Service for Signalized Intersections*

LOS	**Features**	**V/C Ratio****	**HCM Control Delay (s/pcu)**
A	Almost no signal phase is fully utilized by traffic. Very seldom does any vehicle wait longer than one signal cycle. The approach appears open, turning movements are easily made and drivers have virtually complete freedom of operation.	0-0.59	≤ 10
B	An occasional signal cycle is fully utilized and several phases approach full use. Many drivers begin to feel somewhat restricted within platoons of vehicles approaching the intersection.	0.60-0.69	> 10 and ≤ 20
C	The operation is stable though with more frequent fully utilized signal phases. Drivers feel more restricted and occasionally may have to waitmore than one signal cycle, and queues may develop behind turning vehicles. This level is normally employed in urban intersection design.	0.70-0.79	> 20 and ≤ 35
D	The motorist experiences increasing restriction and instability of flow. There are substantial delays to approaching vehicles during short peaks within the peak period, but there are enough cycles with lowerdemand to permit occasional clearance of developing queues and prevent excessive backups.	0.80-0.89	> 35 and ≤ 55
E	Capacity is reached. There are long queues of vehicles waiting upstream of the intersection and delays to vehicles may extend to several signal cycles.	0.90-0.99	> 55 and ≤ 80
F	Saturation occurs, with vehicle demand exceeding the available capacity.	1.0 orgreater	> 80

** Source: TRB 2000*
*** Recommended for use in the Guide*

In summary, the overall level of service of an intersection depends on both the V/C and delays. Long delays can occur when V/C ratios are acceptable, if [6]:

- The cycle length is long;
- A specific lane group has a long red phase; and/or
- The signal progression for the movement is poor.

On the other hand, high V/C ratios (>1.00) can accompany short delays if:

- The cycle length is short;
- The specific lane group has a short red phase; and/or
- The signal progression for the movement is good.

Thus a saturated condition does not necessarily imply a long delay, and vice versa. It is important to assess both the v/c ratio and delay to fully evaluate the operation of a signalized intersection. A well-designed intersection should have acceptable volume to capacity ratios and delays for all movements [6].

Level of service (LOS) is a quantitative stratification of quality of service. Beginning in 1965, the HCM divided highway quality of service into six letter grades, A through F, with A being the best and F being the worst. With the A through F LOS scheme, traffic engineers were able to more easily explain operating and design concepts to the general public and elected officials. Despite its widespread use as an independent measurement, it is important to note that LOS is simply a quantitative breakdown from transportation users' perspectives of transportation quality of service (QOS). LOS reflects the quality of service as measured by a scale of user satisfaction and is applicable to each of the following modes that use roadways: automobiles, trucks, bicycles, pedestrians, and buses [7].

The main objectives of the traffic engineer are to optimize the operation of the existing traffic systems, and solve traffic problems on such intersections. It is important to improve the effectiveness of the traffic control parameters in order to reduce the congestion and to relive the problems that impede the traffic flow along any traffic facility. Therefore; an improvement to the different traffic elements must be considered to increase traffic efficiency and performance. These elements include phase sequences, geometric design elements, parking control, and travel demand management (TDM) actions [8].

The more common kinds of decisions that are made using the signalized intersection capacity analysis module of the HCM include [2], [3]:

- The number of lanes required to accommodate the given traffic demand.
- The signal timing and phasing plan required to serve a given traffic volume.

The signalized intersection procedure requires the following input data [2], [3]:

- The traffic volumes by approach and movement.
- The ideal saturation flow rate.
- The intersection geometry, including number and configuration of lanes
- The signal timing and phasing plan.
- The proportion of heavy vehicles in the traffic stream.
- The grades on the intersection approaches.
- The number of parking maneuvers.

Which of these values are known precisely and which can be only forecasted? For example, the traffic volume can be forecasted.

The above variables can be grouped into three categories:

1. The flow rate data, and related traffic stream characteristics, collected from field or forecasted.
2. Driver behavior for signalized intersections is measured by the saturation headway and it is site specific.
3. The intersection geometry data is usually known to a high degree of accuracy. Even when considering a future project, a specific design is usually developed to the point that the geometric parameters (number of lanes, lane configuration, etc.) are known.

   But the intersection geometry and the signal timing plan for signalized intersections are both fixed by the design parameters that we are considering. The signal timing plan, example, can be developed or synthesized so that for a given design and traffic volume, the intersection will operate in a near optimal manner.

The question here is: if one parameter has changed, how much will this affect the overall operational level of performance for a signalized intersection. Are the signalized capacity analysis and the level of service modules sensitive to small changes in the input parameters? These questions will be answered in the section of operation analysis of this paper.

5- Data Collection:

In order to assess the performance of a selected study area, field observation including traffic volumes and conditions must be collected. The measurements are taken manually on workdays, in which the highest congestion and inefficient use of transportation system occur at peak hours.

5-1 Traffic Volume:

The traffic volume count was carried out at Shahid Hama Rash and SheraiNaqib Intersections from (8:15 a.m to 9:15 a.m) during the workdays of the week and the highest recording traffic volume in each direction is recorded to be used in the analysis of the present study.

The vehicles are classified into two types:

1. *Small vehicles:* any vehicles move on four tires includes the PC.
2. *Large vehicles*: any vehicles move on more than four tires.

The period of the volume counting is divided into 15 minutes intervals; Table (3) show the total a volume for all approaches each one hour at both intersections.

5-2 Existing Geometric Design:

For the operation analysis for both Shahid Hama Rash and SheraiNaqib Intersections, it is very important to specify the number of lanes in addition to the direction of each movement. Figures (2) and (3) demonstrate the existing geometric layout for both intersections.

Table (3) Traffic volume, peak hour factor (PHF), and signal timing at Shahid Hama Rash and SheraiNaqibIntersections for all approaches in the peak hour period

Intersection Name	Collected Data		NB			SB			EB			WB		
			R	TH	L	R	TH	L	R	TH	L	R	TH	L
Shahid Hama Rash Intersection	Traffic volume	8:15-8:30 a.m	-	-	-	-	-	107	-	-	148	-	104	44
		8:30-8:45 a.m	-	-	-	-	-	119	-	-	104	-	103	18
		8:45-9:00 a.m	-	-	-	-	-	83	-	-	151	-	105	24
		9:00-9:15 a.m	-	-	-	-	-	106	-	-	133	-	123	25
		8:15-9:15 a.m	-	-	-	-	-	415	-	-	536	-	435	111
	% HV		-	-	-	-	-	1	-	-	15	-	1	0
	PHF		-	-	-	-	-	87	-	-	89	-	88	63
	Signal Timing (sec)		-			G=25 Y=5			G=25 Y=5			G=25 Y=5		
SheraiNaqib Intersection	Traffic volume	8:15-8:30 a.m	-	22	115	-	39	13	-	66	17	-	176	22
		8:30-8:45 a.m	-	29	86	-	38	17	-	73	21	-	121	54
		8:45-9:00 a.m	-	35	61	-	39	11	-	39	12	-	84	34
		9:00-9:15 a.m	-	19	94	-	33	6	-	60	14	-	111	49
		8:15-9:15 a.m	-	105	356	-	149	47	-	238	64	-	492	159
	% HV		-	2	4	-	2	0	-	11	0	-	11	0
	PHF		-	75	77	-	96	69	-	82	76	-	70	74
	Signal Timing (sec)		G=20 Y=5			G=20 Y=5			G=30 Y=5			G=35 Y=5		

TH: Through movement, R: Right movement, L: Left movement, and % HV: Percent of Heavy Vehicles

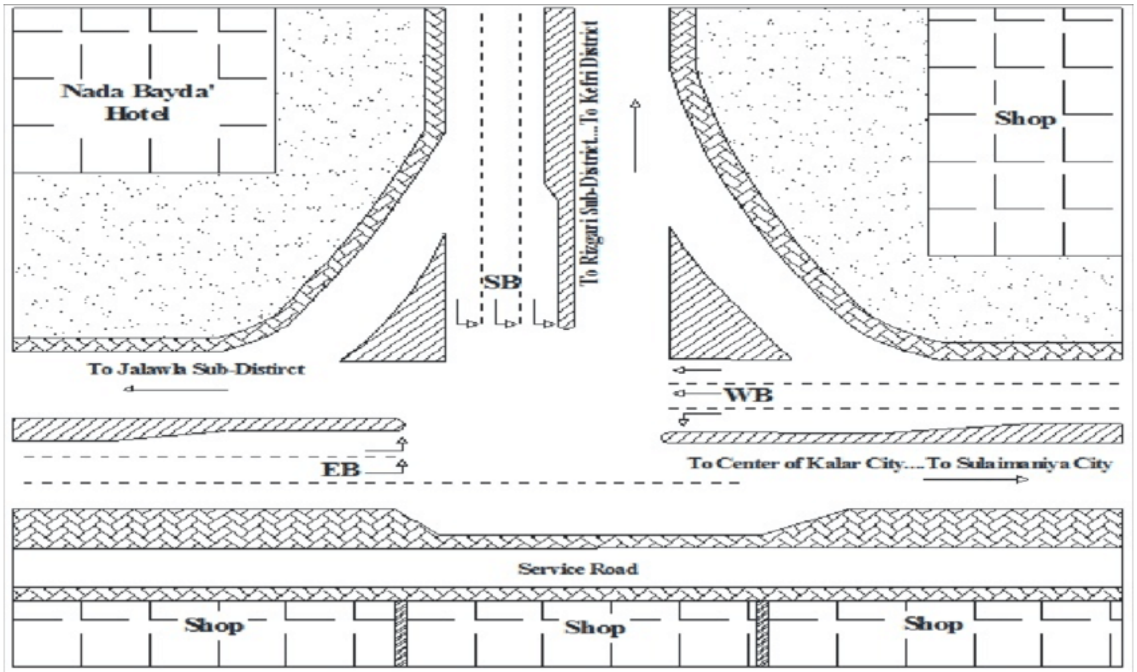

Figure (2) Existing geometric design for Shahid Hama Rash Intersection

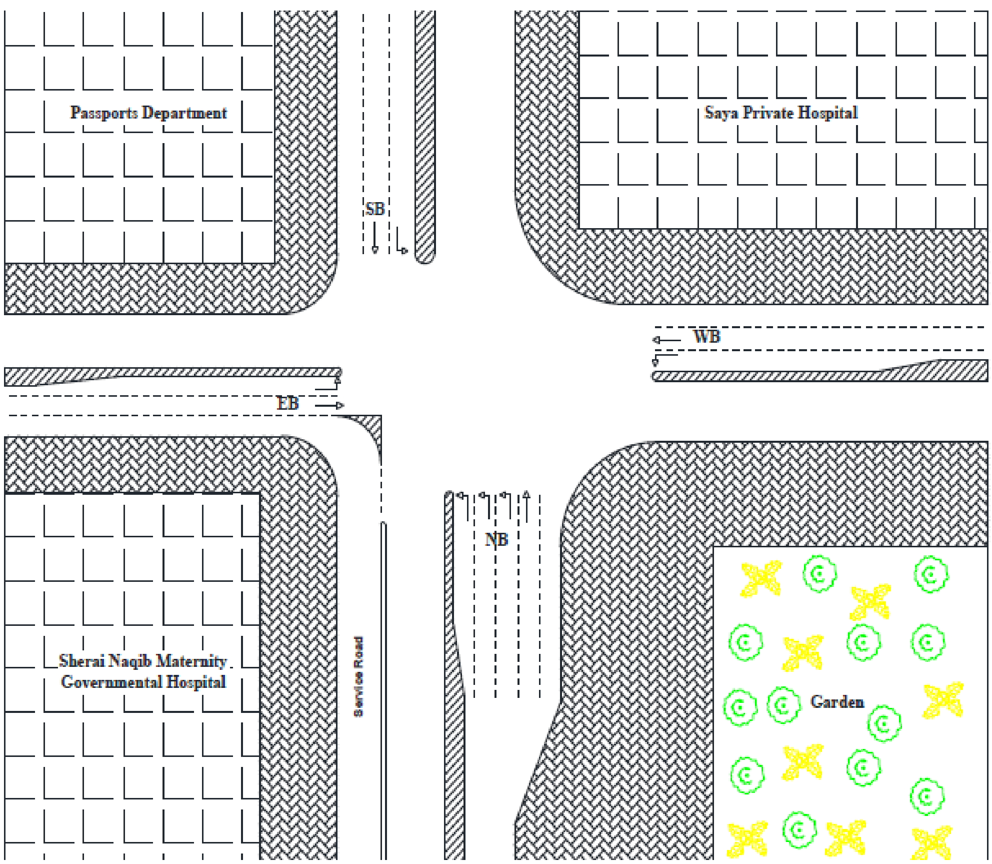

Figure (3) Existing geometric design for SheraiNaqib Intersection

6- Operation Analysis and Measuring the Effect of Changing in the Traffic Variables on the Intersection Performance:

For Operation analysis and measuring the effect of changing in the traffic variables on the intersection performance, HCS-2000 program is used.

6-1 Operation Analysis for the Existing Condition for Shahid Hama Rash andSheraiNaqibIntersections:

For the operation analysis for both Shahid Hama Rash and SheraiNaqib Intersections, HCS-2000 program is used, and the major output results (LOS, delay and v/c) are summarized in Table (4).

Table (4) Operation analysis major outputs results for both Shahid Hama Rash and SheraiNaqib Intersections (data analyzed using HCS program)

Intersection Name	Collected Data	NB			SB			EB			WB		
		R	TH	L	R	TH	L	R	TH	L	R	TH	L
Shahid Hama Rash Intersection	Lane group LOS	-	-	-	-	-	C	-	-	D	-	F	C
	Lane group Delay(sec/veh)	-	-	-	-	-	27.6	-	-	51.6	-	286.0	29.6
	Lane group v/c	-	-	-	-	-	0.47	-	-	0.90	-	1.53	0.29
	Approach LOS	-			C			D			F		
	Approach Delay(sec/veh)	-			27.6			51.6			246.4		
	Intersection LOS	F											
	Intersection Delay(sec/veh)	129.5											
SheraiNaqib Intersection	Lane group LOS	-	D	D	-	D	D	-	E	D	-	F	D
	Lane group Delay(sec/veh)	-	54.5	54.0	-	54.3	47.7	-	63.1	39.5	-	331.0	40.7
	Lane group v/c	-	0.51	0.66	-	0.52	0.23	-	0.81	0.22	-	1.61	0.47
	Approach LOS	D			D			E			F		
	Approach Delay(sec/veh)	54.2			52.3			57.8			263.0		
	Intersection LOS	F											

	Intersection Delay(sec/veh)	145.2

6-2 Measure the Effect of changing in the Traffic Volumes on the Intersection Performance:

Traffic volume is the variable that has the biggest effect on signalized intersection performance. In order to study the effect of variation of traffic volume, the existing volume for both Shahid Hama Rash and SheraiNaqib Intersections has been increased twice and decreased twice by *10%* and *20%*. The overall intersection performance is illustrated in Table (5). It is clearly recognized from the output results that the changing in the traffic volumes (increasing and decreasing) have big effect on intersection delay, and it is good to mention that the effect of increasing the traffic volume on intersection delay is more than the effect of decreasing the traffic volume, but the percentage of the deference is small in most of the cases.

Table (5) Changing the traffic volume and its effect on overall intersection performance for both Shahid Hama Rash and SheraiNaqib Intersections

Intersection Name	Traffic Volume and the Changing in the Traffic Volume	Intersection		
		Delay (sec/veh)	% of Changing in Delay	LOS
Shahid Hama Rash Intersection	Existing traffic volume	129.5	-	F
	Existing traffic volume +10%	160.0	23.55	F
	Existing traffic volume +20%	193.4	49.34	F
	Existing traffic volume -10%	102.7	-20.69	F
	Existing traffic volume -20%	77.3	-40.30	F
SheraiNaqib Intersection	Existing traffic volume	145.2	-	F
	Existing traffic volume +10%	171.0	17.76	F
	Existing traffic volume +20%	198.1	36.43	F
	Existing traffic volume -10%	120.2	-17.21	F
	Existing traffic volume -20%	96.2	-33.34	F

6-3 Measure the Effect of Changing in the Heavy Vehicle Percentage on the Intersection Performance:

The effect of heavy vehicle percentage in the traffic mix has a significant effect on the intersection performance. Table (6) shows that, as the percentage of heavy vehicles increased by *2%*, the intersection performance in terms of delay has increased by *4.47%* for Shahid Hama

Rash Intersection and by *3.37%* for SheraiNaqib Intersection. The percentage change in delay almost doubles when the heavy vehicle percentage in the traffic mix is increased to *4%*.

Table (6) Changing the percentage of heavy vehicle (HV%) and its effect on overall intersection performance for both Shahid Hama Rash and SheraiNaqib Intersections

Intersection Name	Traffic Volume and the Increase in Percentages of Heavy Vehicle (HV%)	Intersection		
		Delay (sec/veh)	% of Changing in Delay	LOS
Shahid Hama Rash Intersection	Existing traffic volume	129.5	-	F
	Existing traffic volume +2% HV	135.3	4.47	F
	Existing traffic volume +4% HV	140.9	8.80	F
SheraiNaqib Intersection	Existing traffic volume	145.2	-	F
	Existing traffic volume +2% HV	150.1	3.37	F
	Existing traffic volume +4% HV	154.7	6.54	F

6-4 Measure the Effect of Changing in the Driver behavior on the Intersection Performance:

Driver behavior is the most important factor that affects the intersection performance. In signalized intersection capacity analysis, driver behavior is measured by saturation headways. Varying the saturation headway shows that driver behavior has a significant effect. Table (7) shows that aggressive drivers (*h=1.7*) have less effect on intersection delay than the non-aggressive drivers (*h=2.1*), but still the deference between the aggressive driver (*h=1.7*) and the non-aggressive driver (*2.1*) in term of the percentage of effect on intersection delay is not big.

Table (7) Changing saturation headway and its effect on overall intersection performance for both Shahid Hama Rash and SheraiNaqib Intersections

Intersection Name	The Grade and the Changing in Saturation Headway	Intersection		
		Delay (sec/veh)	% of Changing in Delay	LOS
Shahid Hama Rash Intersection	Existing saturation headway =1.9	129.5	-	F
	Saturation headway =1.7	101.1	-21.93	F
	Saturation headway =2.1	163.2	26.02	F
SheraiNaqib Intersection	Existing saturation headway =1.9	145.2	-	F
	Saturation headway =1.7	118.6	-18.32	F
	Saturation headway =2.1	174.6	20.24	F

7- Discussion and Conclusions:

From the results of the operation analysis for the existing condition and changing in the traffic variables (traffic volumes, percentage of heavy vehicles and driver behavior) for Shahid Hama Rash and SheraiNaqib Intersections using HCS program, it is noticed the following:

- The existing condition of Shahid Hama Rash and SheraiNaqib Intersections need improvements to reduce their delay time and raise their level of service (LOS).
- Traffic volume is the variable that has the biggest effect on signalized intersection performance. It is clearly recognized from the output results of the operation analysis of the case study of this research (Shahid Hama Rash and SheraiNaqib Intersections) that the changing in the traffic volumes (increasing and decreasing) have big effect on intersection delay, and it is good to mention that the effect of increasing the traffic volume on intersection delay is more than the effect of decreasing the traffic volume, but the percentage of the deference is small in most of the cases.
- The effect of heavy vehicle percentage in the traffic mix has a significant effect on the intersection performance.
- Driver behavior is the most important factor that affects the intersection performance. In signalized intersection capacity analysis, driver behavior is measured by saturation headways. Varying the saturation headway shows that driver behavior has a significant effect. It is recognized from the output results of the operation analysis of the case the study of this paper (Shahid Hama Rash and SheraiNaqib Intersections) that aggressive drivers have less effect on intersection delay than the non-aggressive drivers, but still the deference between the aggressive driver and the non-aggressive driver in term of the percentage of effect on intersection delay is not big.

8- Recommendations:

- From the conclusion of this research, the existing condition of Shahid Hama Rash and SheraiNaqib Intersections need improvements to reduce their delay time and raise their level of service (LOS). As ^{1}st improvement it is recommended to optimize the signal timing for both Shahid Hama Rash and SheraiNaqibSignalized Intersections to reduce the intersection delay, because the current signal timing is not suitable for the traffic volumes in the approaches and cause big amount of congestion and delay.

- More researches to study with details the effect of traffic variables on the performance of the signalized intersections, and each research should focus on one traffic variable to obtain more specific and accurate results that reflect the effect of each traffic variable on the signalized intersection performance.

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