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Evaluation The Performance of Al-Thawra At-Grade Intersection Using The HCS2000 Computer Package

Ali Majeed K.Al-Ubadiy*, Zeena Tariq Al-Azzawi* & Nawal Dawood S.

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Abstract

Al-Thawra signalized intersection is one of the most important intersections in AL-Hilla city because it relates the Governorates: Baghdad, Najaf, Kerbala and Babel, and serves of about 21000000 passages of vehicles yearly. The excessive traffic volumes, during the peak periods (at morning and evening), of vehicles that entering the intersection increase traffic density, reduce travel speed, increase travel time, and increase the delay values. The delay values are reflected by McTrans Center, University of Florida {Highway Capacity Manual (HCM2000)} to an indicator named LEVEL OF SERVICE (LOS). The operational analysis of the existing conditions of this intersection by the Highway Capacity Software (HCS2000) indicates that the LOS of it equal to (F) with an intersection delay value of 263.7 sec./vehicle and a degree of saturation exceeds 1.5. 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 (Baghdad-60St.) 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 Baghdad to Najaf {60 St.} and vice versa) from the other movements of the intersection The results indicate that the intersection LOS equal (**C**) with a cycle time of (**58**) sec. and an intersection delay of (**22.8**) (sec./veh.) at the object year 2027.

Keywords: Signalized intersection, HCM, HCS, Delay time, Cycle time.

تقييم أداء تقاطع الثورة باستخدام برنامج (HCS2000)

الخلاصة

إن تقاطع الثورة الذي يقع في محافظة بابل (مدينة الحلة) هو أحد التقاطعات المهمة في المحافظة حيث أنه يربط محافظات بغداد, النجف الأشرف, كربلاء المقدسة ومحافظة بابل ويخدم ما يقارب من 21000000 مركبة سنوياً.

إن زيادة الحجوم المرورية يكون عادة في أوقات الذروة (صباحاً ومساءاً) في هذا التقاطع مما يزيد من الكثافة المرورية و يقلل من سرعة المركبات ويزيد من أوقات الرحلات و بالتالي زيادة أوقات التأخير عند المرور بهذا التقاطع. وكما هو معروف فإن أوقات التأخير تعد العامل الرئيسي في تقييم مستوى خدمة التقاطعات وكما يعتمده دليل سعة الطرق (Highway Capacity Manual). لذا وبعد دراسة هذا التقاطع تم من خلال برنامج (HCS2000) حساب قيمة أوقات التأخير الكلية على هذا التقاطع و التي بلغت 263.7 (ثانية/مركبة) والذي يشير بدوره إلى أن مستوى خدمة هذا الطريق بموجب تصنيف الـ (HCM) هو (F) بدرجة تشبع (حجم مروري/سعة مرورية) مقدارها 1.5؛ لذا وللأسباب المذكورة أعلاه من الضروري تحسين أداء هذا التقاطع.

في هذا البحث تم اقتراح عدة بدائل و كان البديل الأفضل هو فصل الحركات المتقاطعة ضمن هذا التقاطع بجسر مع زيادة عدد الممرات فيه والتحكم بباقي حركات التقاطع بإشارة ضوئية.

*Building and Construction Engineering Department, University of Technology, Baghdad

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2412-0758/University of Technology-Iraq, Baghdad, Iraq

أشارت المسوحات المرورية بأن المرور المتجه من شمال التقاطع إلى جنوبه وبالعكس (بغداد-نجف وبالعكس) له التأثير الأكبر على أداء التقاطع؛ لذا تم اقتراح إنشاء جسر يحمل الحجوم المرورية ضمن هذا الاتجاه و يتكفل التقاطع أسفل الجسر بباقي الحجوم والاتجاهات المرورية. وبعد دراسة ما سيكون عليه أداء التقاطع في سنة الهدف 2027 وجد بأن قيمة وقت التأخير عند التقاطع ستكون 22.8 ثانية/مركبة بمستوى خدمة (C) وبوقت دورة للتقاطع قيمتة 58 ثانية.

1- Introduction:

Al-Thawra signalized intersection is one of the most important intersections in AL-Hilla citybecause it relates the Several Governorates: Baghdad, Najaf, Kerbala and Babel, as shown in Figure (1), and serves of about 21000000 passages of vehicles yearly.

The excessive traffic volumes, during the peak periods (at morning and evening), of vehicles that entering the intersection increase traffic density, reduce travel speed, increase travel time, and increase the delay values. The delay values are reflected by McTrans Center, University of Florida {Highway Capacity Manual (HCM2000)} to an indicator named LEVEL OF SERVICE (LOS). The operational analysis of the existing conditions of this intersection by the Highway Capacity Software (HCS2000) indicates that the LOS of it equal to (F) with an intersection delay value of 263.7 sec./vehicle and a degree of saturation exceeds 1.5. Therefore, and because of the reasons above, it is important to improve the performance of Al-Thawra Intersection.

To study and evaluate the existing conditions in the intersection, the following items are required

a) Data collection of the existing traffic volumes for each approach (Left, Through, and Right) within the intersection.
b) From the above traffic volume data, the peak (15 min.) volume, as well as, the peak hour factor can be obtained
c) Determination of the existing LOS, under existing conditions of geometry and traffic operation, by using HCS2000 program.
d) Estimation of traffic volume at the designed year (2027).
e) Proposed suitable solutions that may be improved the performance of the intersection depending on the traffic volumes and movements and the availability of free spaces.
f) Evaluation of the suggested proposals under the estimated traffic volumes at the object year 2027.

2- Data Collection:

To determine the existing traffic volumes of Al-Thawra intersection, a digital camera is used. The peak hour periods (morning and evening) is then found at 8:00-9:00 morning and 1:00-2:00 evening. The traffic volumes are collected at 25/6/2007 for each approach, as well as, for each movement from the movie and tabulated in Table (1) below.

From the data of Table (1), the peak period at morning is used to analyze the intersection and determine the existing intersection LOS. It is important to note, from the traffic counting, some approaches make the Peak Hour Factor (PHF) of the intersection less than 0.90 because:

$$PHF = \frac{Total\ \ Traffic\ \ Volume\ \ for\ \ one\ \ hour}{(Higher\ \ traffic\ \ volume\ \ for\ \ 15\,\text{min})*4} .....(1)$$

In the same way, from the traffic counts, it can be seen that the through traffic volume in the North-South direction (Baghdad-Najaf 60St.) is the highly traffic volume in the intersection. This means that the improvements should take this direction into considerations to improve the intersection performance.

3- Overview of the Highway Capacity Manual and Its Software:

The *Highway Capacity Manual* (HCM) provides transportation practitioners and researchers with a consistent system of techniques for the evaluation of the quality of service on highway and street facilities. The HCM does not set policies regarding a desirable or appropriate quality of service for various facilities, systems, regions, or circumstances. Chapter 16 of HCM2000 contains a methodology for analyzing the capacity and level of service (LOS) of signalized intersections. The analysis must consider a wide variety of prevailing conditions, including the amount and distribution of traffic movements, traffic composition, geometric characteristics, and details of intersection signalization. The methodology focuses on the determination of LOS for known or projected conditions. The methodology addresses the capacity, LOS, and other performance measures for lane groups and intersection approaches 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 seconds per vehicle). Control delay is the portion of the total delay attributed to traffic signal operation for signalized intersections. Control delay includes initial deceleration delay, queue move-up time, stopped delay, and final acceleration delay. Figure (2) shows the input and the basic computation order for the method. The primary output of the method is level of service (LOS). This methodology covers a wide range of operational configurations, including combinations of phase plans, lane utilization, and left-turn treatment alternatives. It is important to note that some of these configurations may be considered unacceptable by some operating agencies from a traffic safety point of view. The safety aspect of signalized intersections cannot be ignored, and the provision in this chapter of a capacity and LOS analysis methodology for a specific operational configuration does not imply an endorsement of the suitability for application of such a configuration.

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 Table (2). On the other hand, Table (3) provides a summary of the input information required to conduct an operational analysis for signalized intersections. This information forms the basis for selecting computational values and procedures in the modules that follow. The data needed are detailed and varied and fall into three main categories: geometric, traffic, and signalization. The input worksheet is shown in Figure (3).

4- Description of the Selected Program (HCM2000):

Highway Capacity Software (HCS 2000) was developed by the Mctrans center at the University of Florida as a typical windows installation. This version of the HCS implements the procedures defined in the 2000 Highway Capacity Manual (HCM 2000) which is a copyright 2000 by the Transportation Research Board.

HCS 2000 comprises a complete new release of the HCS upgrading modules to incorporate. Procedures in both US and metric units to faithfully implement the HCM 2000. The freeways, weaving, ramps. multilane, signals, unsignals and arterials modules have been upgraded. HCS 2000 also adds several new features, including a new graphic entry option for lane configuration and volume data and global spinners for PHF and volumes (incrementing by a specific percentage for sensitivity analysis) in the signal and unsignal modules.

4-1 Signalized Intersection in HCS 2000 (2002) Computer Program

****Input Operation Data***

First the user enters the general information into the respective fields: Analyst, Agency or company, data performed and analysis time period. Then the user enters the site information into the respective fields: intersection, jurisdiction, analysis year and project description. The east/west street name and north/south street name data may be used to extract the appropriate information for use in an arterials analysis if a signals file is referenced.

Input Quick jump and report quick jump are pull – down lists from which to select. A specific place in the input or report screens to be positioned. Simply click on either field and select the portion of the input or report screens to move to and appropriate screen will position itself here.

Quick Entry takes the user to a graphic data entry screen as an alternate method for coding traffic volume and lane configuration data. In the Quick entry screen, the user first selects an approach from the EB (east bound), WB (west bound) NB (north bound) and SB (south bound) buttons in the lower right corner. Then the lane combination can be selected by clicking on appropriate arrows to place them on the central diagram next turning volumes (left, thru and right)can be entered for the selected approach which will also be transferred to the central diagram, for an overall view of the intersection . These data are coordinated with the normal data entry screen so that changes in either view are reflected in the other.

Then the user codes the traffic volume for each movement of the intersection in vehicles per hour. An hourly volume is required for any movement to be included in the analysis. There is an optional globule spinner at the end of the traffic volume row that will allow the coded volumes to be incremented by the percentages hour in the all volume field using the adjacent spinner. This is especially useful when doing sensitivity analyses for various growth rates. Either peak Hour factor (PHF-peak 15-minute volume, Right turns on red , number of usage lane , Average Queue spacing (Lh), storage length (La) and Adjusted flow rate are entire.

**** Operating Parameters***

Either the arrival type or proportion arriving during green is coded to define the quality of progression. The arrival type is coded from 1 to 6 with being poor progression, 2 being unfavorable progression, 3 being random arrivals, 4 being favorable progression, 5being highly favorable progression and 6 being exception progression. Crosswalk length, pedestrian speed and crosswalk width are entered to calculate the minimum green in seconds required to accommodate pedestrian operations.

**** Phasing***

The phase design area is used to enter the inter section timing plan. Timing must be determined by external means, other programs or manual methods. HCS does not estimate timing. Phase design is coded using up to eight phase area to define combinations of movements and timing. Each distinct phase is defined by coding the green, yellow and red (all red) times in seconds with all movements allowed during each phase.

**** Saturation Flow***

The ideal saturation flow rate is coded for each lane group, and then adjusted by using the equation in HCM.

S = So N Fw FHv Fg Fp Fbb Fa Flu Flt Frt Flpb Frpb

Where:
S= saturation flow rate for subjected lane group, expressed as a total for all lanes in lane group (veh/h).
So= base saturation flow rate per lane (Pc/h/in).
N= number of lanes.
Fw= adjustment factor for lane width.
FHv= adjustment factor for heavy vehicle in traffic stream.
Fg= adjustment factor for approach grade.
Fp= adjustment factor for existence of a parking lane and parking lane and parking activity adjacent to lane group.
Fbb= adjustment factor for blocking effect of local buses that stop within intersection area.
Fa= adjustment factor for area type.
Flu= adjustment factor for lane utilization.
Flt= adjustment factor for left turns in lane group.
Frt= adjustment factor for right turns in lane group.
Flpb= pedestrian adjustment factor for left-turn movement.
Frpb= pedestrian. Bicycle adjustment factor for right turn movements.

**** The Results***

The Lane group capacity is computed for each lane group by multiplying the adjusted saturation flow rate by the g/c ratio. The lane group v/c ratio is calculated by dividing the adjusted flow rate by the lane group capacity.

The back of Queue is the number of vehicles that are queued depending on arrival patterns of vehicles and vehicles that do not clear the intersection during a given green phase.

The lane group delay is calculated as the sum of the uniform delay (d1) as adjusted by the progression factor (pf), incremental delay (d2) and initial Queue delay (d3). The lane group level of service is then determined from comparing the lane group delay with the thresholds defined in HCM Exhibit 16-2-

Approach delay is calculated as the average delay for each lane group weighted by the lane group flow rate as defined in HCM equation 16-14 which is:

$$d_1 = \frac{\sum d_A V_A}{\sum V_A}$$

The approach level of service is then determined from comparing the approach delay with the thresholds defined in HCM Exhibit 16-2.

Intersection delay is calculated as the average delay for each approach weighted by the lane group flow rate as defined in HCM equation 16-15. The intersection level of service is then determined from comparing the intersection delay with the thresholds defined in HCM Exhibit 16-2.

5- Some Traffic Improvement Studies:

Many traffic improvement studies were made in Iraq. Some of these studies used HCS program for evaluation process and providing the optimal single timing data. These are some of these studies:

First example: the study that carried out by [AL-Arkwazze, 2003] in 14th-Ramadhan arterial street in Baghdad city. This arterial street consists of six signalized intersections, which suffer from high congestion level especially during (8:30-9:30) a.m peak period because of high traffic volumes and bad timing plan. Five improvements were suggested by [AL-Arkwazze, 2003] to decrease the congestion problem in the study area.

[Abdul-Ghani 2004] studied three important streets (AL-Rashid, AL-Khalafa and AL-Kifah) which are located in Central Business District area. The area of study consists of thirteen intersections. This area suffer from sever congestion conditions, especially at time between (10:00-12:00) a.m and (1:30-3:30) p.m. period because of many activities. Centers such as government institutions, ministries so the aim of the study was to relieve the traffic problems by suggesting several alternatives.

6- Operational Analysis of the Existing Conditions:

The operational of the existing geometrical features and traffic volumes of Al-Thawra intersection is performed using HCS2000. Table (4) illustrates the results of analysis. The results indicate that the intersection LOS is (F) with an average intersection delay of 263.7 sec./vehicle. Therefore, the improvements are required to reduce the intersection delay and change the LOS.

7- Proposal Improvement of Traffic Performance:

In order to improve the traffic performance in the study area, improvement proposals will be explained in the following section.

7-1 Proposal NO 1: Changing the cycle length for the intersection:

In this proposal, several cycle lengths are examined using HCS program. From the result, it is noticed that the (LOS) for the intersection is (F) ,therefore, the proposal is not good enough for the intersection. Table (5) shows the results for this proposal for the cycle time 168 sec. as example. The results are based on existing traffic volume observed at the selected signalized intersection.

7-2 Proposal NO 2: Increasing the number of lanes in each direction:

In this proposal, changing of geometric design for the intersection by increasing the number of lanes in each approach is suggested. It was found that the LOS of the intersection is still F with an overall delay of (200.6) sec/veh.

7-3 Proposal NO 3: Construct an overpass bridge:

The traffic survey shows that the high traffic volume of through movement of the North-South direction (Baghdad-60St.) 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 Baghdad to Najaf {60 St.} and vice versa) from the other movements of the intersection.

7.3.1 Future Traffic Volume:

The geometric design of new highway facilities or improvements to existing highways should not usually be based on the current traffic volumes only, but should consider future traffic volumes that may uses the facility. Many highway designers believe the maximum design period is in the range of 15 to 24 years. Therefore, a design period of 20 years is widely used. The traffic flow within this period cannot usually be expected accurately because of the probable changes in the general regional economy, population, and land use and development around the facility, which cannot be predicted with any degree of assurance. With this preface, the selected design life for Al-Thawra Intersection is 20 years with an annual growth rate of 3% which reflects the socioeconomic nature of Babel city. The necessary calculation for the projection of the current traffic volumes to represent the future traffic in the design year 2027 is:

Future traffic volume at (2027) = Current traffic volume at (2007) * Growth factor.

Growth factor =

$$(1 + Annual\ Growth\ Rate)^{Design\,Life(years)} \quad \ldots\ldots(2)$$

Therefore: Growth factor = $(1+0.03)^{20} = 1.8$

Therefore, the future traffic volumes for the effective movements in Al-Thawra Intersection are tabulated in Table (5) below.

7.3.2 The proposed Geometric Design:

After considering the future traffic volumes for the different movements in the intersection, the proposed geometric design can be seen in Figure (4). The design represents the unique solution to improve the performance of the intersection.

The proposed design is based on the concept of eliminating the heaviest through traffic volume from Baghdad to Najaf and vice versa. The proposed **four lane** overpass will accommodate the future traffic volume in this direction (North-South) with an acceptable LOS of (C). The use of traffic signals to control the traffic movements within the intersection with the aid of improvements (overpass) and channelizations will participate into large extent in intersection performance betterment and make operation of the intersection under an acceptable LOS at the design year (2027).

On the other hand, the suggested geometric design of the at-grade intersection is tabulated in Table (7) below.

7.3.3 Interchange Performance Analysis at 2007 & at the Design Year (2027):

The collected traffic volumes at 25/6/2007 are used to predict the interchange LOS after considering the proposed geometric design. Table (8) shows the HCS summarized results of averaged delay and LOS.

After considering the proposed geometric design, a new signal phasing plan with new signal timing is used to evaluate the intersection LOS under the predicted traffic demand at the year 2027 by HCS2000. The signal phasing plan is shown in Figure (5) and the summary of the results is given in Table (9). The results indicate that the intersection LOS equal (**C**) with a cycle time of (**58**) sec. and an intersection delay of (**22.8**) (sec./veh.).

8- Summary:

Al-Thawra signalized intersection is one of the most important intersections in AL-Hilla citybecause it relates the Governorates: Baghdad, Najaf, Kerbala and Babel, and serves of about 21000000 passages of vehicles yearly.

The operational analysis of the existing conditions of this intersection by the Highway Capacity Software (HCS2000) indicates that the LOS of it equal to (F) with an intersection delay value of 263.7 sec./vehicle and a degree of saturation exceeds 1.5. Therefore, and because of the reasons above, three improvement proposals were suggested. The study showed that an overpass over the heaviest traffic volume direction is the best solution to improve the intersection performance. The results indicated that the intersection measures of effectiveness at the goal year (2027) will be:

- LOS = **C**
- Intersection delay = **22.8** (sec./veh.) with an intersection cycle time = **58** (sec.).

9- References:

1- **Abdul - Ghani**, **M.M., (2004)**, “Evaluation and Improvement of Traffic Flow Patterns for a selected CBD Area in Baghdad City”, M.Sc., Thesis.
2- **Al-Arkwazze, S.A**., **(2003)**, “Capacity Improvement of 14th Ramadhan Street in Baghdad city”, M. Sc. Thesis, University of Technology.
3- **Google Earth Software.**
4- **HCM 2000,** Mc Trans, Center for Transportation Microcomputers in Transportation Research Center, (2002), university of Florida, “HCM-2000 Users Manual”, January.

Table (1) Collected Traffic volumes for Peak Periods (morning & evening).

East Bound (from Kerbala to Hilla)						
Period	Left		Through		Right	
	PC*	HV**	PC	HV	PC	HV
8:00-8:15	81	13	89	16	35	5
8:15-8:30	141	12	114	19	32	0
8:30-8:45	150	10	82	13	25	0
8:45-9:00	136	9	96	14	30	4

Table (1) Continued.

East Bound (from Kerbala to Hilla)						
Period	Left		Through		Right	
	PC*	HV**	PC	HV	PC	HV
1:00-1:15	62	9	66	11	26	4
1:15-1:30	104	9	84	14	24	0
1:30-1:45	117	7	64	10	19	0
1:45-2:00	101	7	71	11	22	2
West Bound (from Hilla to Kerbala)						
8:00-8:15	122	10	117	43	57	0
8:15-8:30	114	4	131	52	53	2
8:30-8:45	140	7	184	57	65	0
8:45-9:00	127	4	153	45	67	0
1:00-1:15	90	7	87	32	42	0
1:15-1:30	84	3	97	39	39	1
1:30-1:45	104	5	138	43	48	0
1:45-2:00	94	3	113	33	50	0
North Bound (from Najaf {60 st.} to Baghdad)						
8:00-8:15	96	4	119	13	149	7
8:15-8:30	156	6	161	12	153	4
8:30-8:45	130	2	187	17	115	1
8:45-9:00	123	5	175	12	118	0
1:00-1:15	72	3	88	9	110	5
1:15-1:30	117	4	117	8	113	3
1:30-1:45	96	2	144	12	87	1
1:45-2:00	91	3	132	9	87	0
South Bound (from Baghdad to Najaf {60 st.})						
Period	Left		Through		Right	
	PC	HV	PC	HV	PC	HV
8:00-8:15	43	13	191	6	20	4
8:15-8:30	36	10	250	10	42	3
8:30-8:45	47	15	169	6	19	0
8:45-9:00	44	17	171	7	25	2
1:00-1:15	32	10	141	5	15	3
1:15-1:30	27	34	185	7	31	2
1:30-1:45	35	45	125	5	14	0
1:45-2:00	32	44	127	5	19	1

* PC=Passenger Car.
** HV=Heavy Veahicles.

Table (2) LOS criteria for signalized intersections.

LOS	Control delay per vehicle (sec./veh.)
A	≤ 10
B	>10-20
C	>20-35
D	>35-55
E	>55-80
F	>80

Ref.: HCM2000

Table (3) Input data needs for each analysis lane group.

Type of condition	Parameter
Geometric Conditions	Area type Number of lanes, N Average lane width, W (m) Grade, G (%) Existence of exclusive LT or RT lanes Length of storage bay, LT or RT lane, Ls (m) Parking

Table (3) Continued.

Type of condition	Parameter
Traffic Conditions	Demand volume by movement, V (veh/h) Base saturation flow rate, so (pc/h/ln) Peak-hour factor, PHF Percent heavy vehicles, HV (%) Approach pedestrian flow rate, vped (p/h) Local buses stopping at intersection, NB (buses/h) Parking activity, Nm (maneuvers/h) Arrival type, AT Proportion of vehicles arriving on green, P Approach speed, SA (km/h)
Signalization Conditions	Cycle length, C (s) Green time, G (s) Yellow-plus-all-red change-and-clearance interval (intergreen), Y (s) Actuated or pretimed operation Pedestrian push-button Minimum pedestrian green, Gp (s) Phase plan Analysis period, T (h)

Ref.: HCM2000

Table (4) HCS Results of the Existing Conditions.

Direction		Movement	Degree of saturation	Average delay (sec./veh.)	LOS
EB	From Kerbala to Hilla	Left	1.04	107.1	F
		Through	1.51	304.5	
WB	From Hilla to Kerbala	Left	1.92	489.5	F
		Through	1.44	266.2	
NB	From Najaf {60 st.} to Baghdad	Left	1.86	457.5	F
		Through	1.09	119.3	
SB	From Baghdad to Najaf {60 st.}	Left	0.65	61.3	F
		Through	1.41	250.9	
Overall Intersection				**263.7**	**F**

Table (5) HCS Results of the Proposal No. 1.

Direction		Movement	Average delay (sec./veh.)	LOS
EB	From Kerbala to Hilla	Left	90.4	F
		Through	261.5	
WB	From Hilla to Kerbala	Left	431.4	F
		Through	224.8	
NB	From Najaf {60 st.} to Baghdad	Left	561.6	F
		Through	150.6	
SB	From Baghdad to Najaf {60 st.}	Left	69.1	F
		Through	295.6	
Overall Intersection			**264.5**	**F**

Table (6) Future Traffic Volumes at the year 2027.

Direction		Movement	Future traffic volume at 2027
EB	From Kerbala to Hilla	Left	994
		Through	797
WB	From Hilla to Kerbala	Left	950
		Through	1408
NB	From Najaf {60 st.} to Baghdad	Left	940
		Through	1253
SB	From Baghdad to Najaf {60 st.}	Left	405
		Through	1458

Table (7) The Suggested Geometric Design of the Interchange.

Direction		Movement	Number of lanes
EB	From Kerbala to Hilla	Left turn	4 (At-Grade)
		Through	4 (At-Grade)
WB	From Hilla to Kerbala	Left turn	3 (At-Grade)
		Through	5 (At-Grade)
NB	From Najaf {60 st.} to Baghdad	Left turn	5 (At-Grade)
		Through	2 (Overpass)
SB	From Baghdad to Najaf {60 st.}	Left turn	5 (At-Grade)
		Through	2 (Overpass)

Table (8) HCS Results of the Proposed Interchange at 2007.

Direction		Movement	Phase	Green/ Yellow Time, sec.	Average delay (sec./veh.)	LOS
EB	From Kerbala to Hilla	Left	1	19/2	15.6	B
		Through(*)			15.2	
		Right (**)			-	
WB	From Hilla to Kerbala	Left	2	18/2	17.4	B
		Through(*)			17.2	
		Right(**)			-	
NB	From Najaf {60 st.} to Baghdad	Left	3	15/2	18.2	B
		Through			-	
		Right(**)			-	
SB	From Baghdad to Najaf {60 st.}	Left	3	15/2	17.0	B
		Through			-	
		Right(**)			-	
Overall Interchange					**16.8 sec./veh.**	**B**

(*) The Trough movement of the east-west direction is separated by an overpass.
(**) The Right Turn movement is separated by an triangular island.

Table (9) HCS Results of the Proposed Interchange at 2027.

Direction		Movement	Phase	Green/ Yellow Time, sec.	Average delay (sec./veh.)	LOS
EB	From Kerbala to Hilla	Left	1	15/2	19.1	B
		Through(*)			17.8	
		Right (**)			-	
WB	From Hilla to Kerbala	Left	1	15/2	26.0	C
		Through(*)			25.4	
		Right(**)			-	
NB	From Najaf {60 st.} to Baghdad	Left	2	21/2	25.8	C
		Through			-	
		Right(**)			-	
SB	From Baghdad to Najaf {60 st.}	Left	3	19/2	18.0	B
		Through			-	
		Right(**)			-	
Overall Interchange					**22.8 sec./veh.**	**C**

(*) The Trough movement of the east-west direction is separated by an overpass.
(**) The Right Turn movement is separated by a triangular island.

Figure (1) Existing geometry of Al-Thawra Intersection (Source: Google Earth 2005).

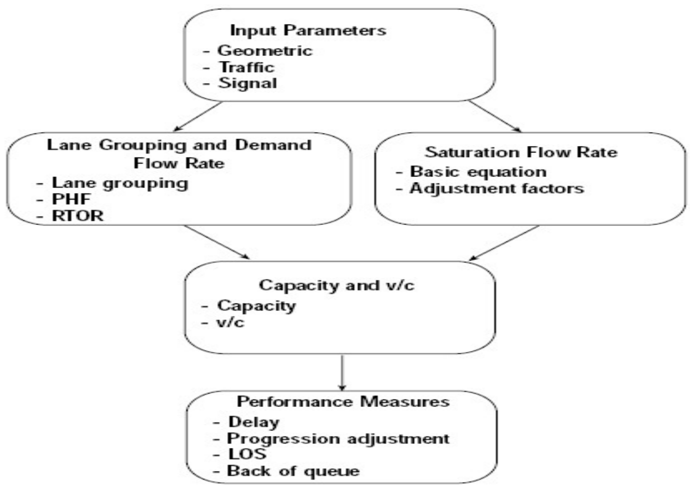


Figure (2) Signalized intersection methodology.
Ref.: HCM2000

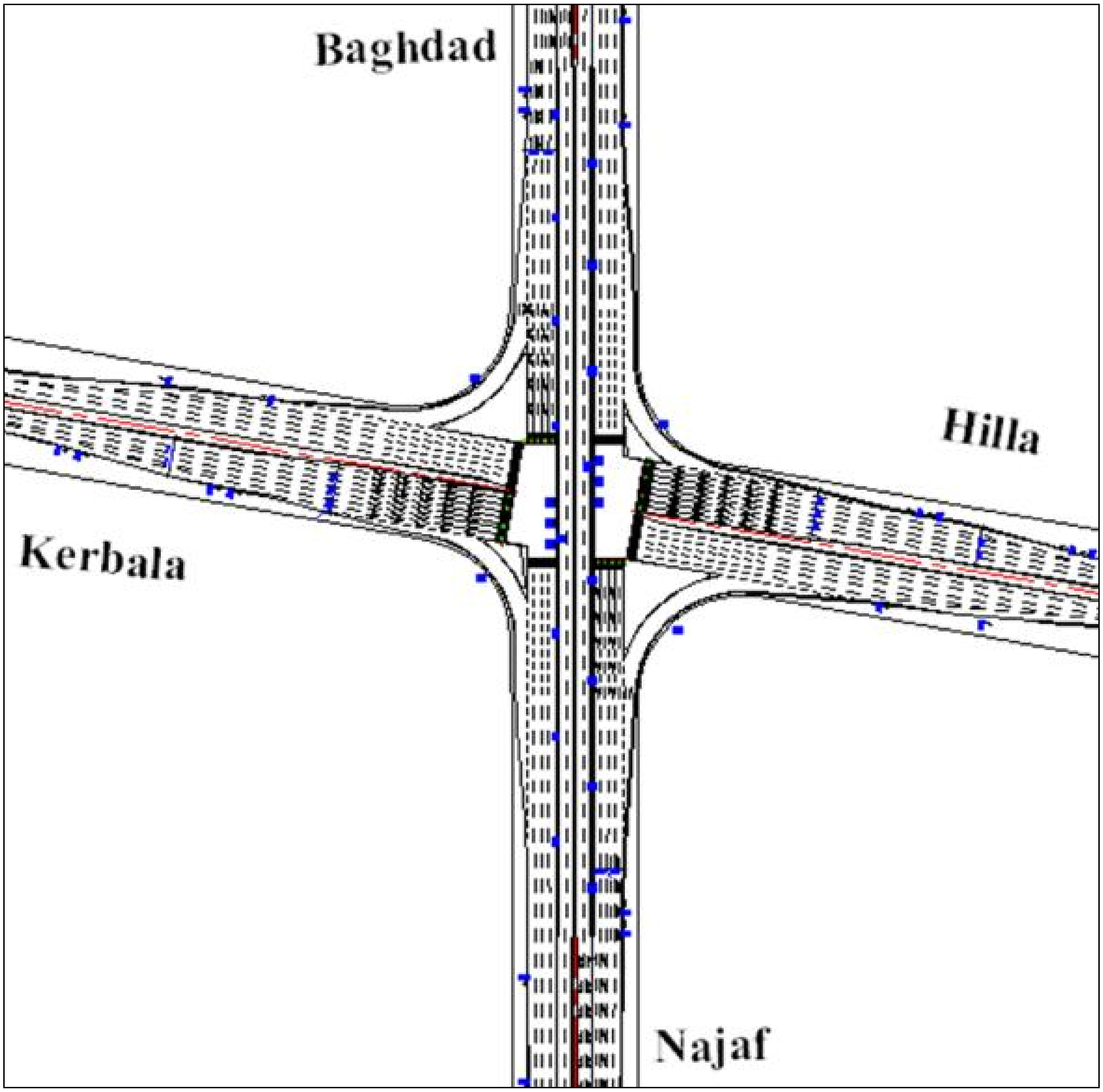


Figure (3) The proposed Geometric Design of Al-Thawra Intersection.

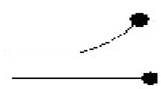
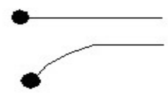
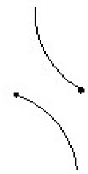
	Phase 1	Phase 2	Phase 3
Diagram			
Movement	From Kerbala to Hilla and Baghdad	From Hilla to Kerbala and Najaf	From Baghdad to Hilla & from Najaf to Kerbala
Timing	Green = 19.0 sec. Yellow = 2.0 sec.	Green = 18.0 sec. Yellow = 2.0 sec.	Green = 15.0 sec. Yellow = 2.0 sec.
Cycle time = 58.0 sec.			

Figure (4) Signal Phasing of Al-Thawra Intersection.