Improvement of Traffic Movement for Roads Network in Al-Kadhimiya City Center

Dr. Mohammed Qadir Ismael
Assistant Professor
College of Engineering – University of Baghdad
drmohammedalbayati@gmail.com

Ali Jasim Mohammed
M.Sc., Transportation Eng.
College of Engineering – University of Baghdad
alij.itas@yahoo.com

ABSTRACT

Numerous regions in the city of Baghdad experience the congestion and traffic problems. Due to the religious and economic significance, Al-Kadhimiya city (inside the metropolitan range of Baghdad) was chosen as study area. The data gathering stage was separated into two branches: the questionnaire method which is utilized to estimate the traffic volumes for the chosen roads and field data collection method which included video recording and manual counting for the volumes entering the selected signal intersections. The stage of analysis and evaluation for the seventeen urban roads, one highway, and three intersections was performed by HCS-2000 software.The presented work plots a system for assessing the level of service for roads network within the study region. Moreover, several improvement alternatives were proposed to overcome the traffic movement operations issues. This work shows that traffic facilities currently undergoing serious degradation causing a traffic jam. Therefore, the implementation of some remedial action is necessary to improve the level of service for these facilities.

Key words: Kadhimiya, traffic, level of service, improvement, network.

تحسين الحركة المرورية لشبكة الطرق في مركز مدينة الكاظمية

د. محمد قادر اسماعيل
أستاذ مساعد
كلية الهندسة – جامعة بغداد

علي جاسم محمد
ماجستير هندسة مواصلات
كلية الهندسة – جامعة بغداد

الخلاصة

تعاني العديد من المناطق في مدينة بغداد من الاختناقات والمشاكل المرورية. نظرا للاهمية الدينية والاقتصادية تم اختيار مدينة الكاظمية (داخل حدود امانة بغداد) كمنطقة دراسة. تم تقسيم مرحلة تجميع المعلومات الى مرحلتين : طريقة الاستبانة والتي استخدمت لتقدير الحجومات المرورية للطرق المختارة وطريقة تجميع البيانات الموقعي وتتضمن التسجيل الفديوي والعد اليدوي للحجوم الداخلة للتقاطعات المختارة. مرحلة التحليل والتقييم لسبعة عشرطريق حضري، طريق سريع واحد وثلاث تقاطعات تم اجراؤها باستخدام برنامج HCS-2000. يرسم العمل المقدم نظاما لتقييم مستوى الخدمة لشبكة الطرق ضمن منطقة الدراسة.علاوة على ذلك اقترحت عدة بدائل للتحسين للتغلب على مشاكل عمليات الحركة المرورية. يبين هذا العمل ان المنشآت المرورية المختارة حاليا تمر بفترة تراجع خطير مؤدية الى حالات توقف تام ولذلك فمن الظروري تطبيق بعض خطوات المعالجة لتحسين مستوى الخدمة لهذه المرافق.

الكلمات الرئيسة : الكاظمية , مرور , مستوى الخدمة , تحسين , شبكة .

1. INTRODUCTION

It is gloabaly recognazied that transportation system is a principal component of the economic, social, cultural and political structure of our society. In recent years, significant changes in both of emphasis and scope of urban transportation planning have occurred. Traffic engineering plays a vital role in reducing the time of journeys, reducing accidents and increasing safety, reducing traffic congestion, increasing the speed of the vehicle, and obtaining information for the geometrical design of various roads components. The ultimate form of intersection control is the traffic signal due to its alternate ability to assign right-of-way to a specific movement, it can substantially reduce the number and nature of intersection conflicts as no other form of control can, **McShane, 2004**. The signalized intersection is generally representing the capacity constraint on any network of streets and is the most complex location in the traffic system. Therefore, the analysis of these locations must consider a wide variety of prevailing conditions, including geometric of the intersection, turning movements, relative approach volumes, traffic composition, and the details of intersection signalization, **Edwards, 1992**.

2. DELAY AT SIGNALIZED INTERSECTIONS

The delay is one of the most important Measures of Effectiveness (MOEs) in traffic studies. It represents the direct cost of fuel consumption and the indirect cost of time loss to the motorist, **Sadegh and Radwan, 1988**. **Webster**, **1958**, presented the results of his research conducted at the road research laboratory in London. The research was focused on vehicle delay at fixed traffic signals and optimum sitting of such signal. They used the simulation technique to simulate the behavior of traffic. They assumed that vehicles arrive at the random pattern.

The collected delay values are analyzed and the model below was adopted to represent the simulated data:

$$d = \frac{C(1-\lambda)^2}{2(1-\lambda X)} + \frac{X^2}{2q(1-X)} - 0.65\left[\frac{C}{q^2}\right]^{1/3} .X^{(2+5\lambda)} \quad (1)$$

where:

d= the average delay per vehicle, sec,
C= cycle time, sec,
λ= proportion of the cycle time, which is effectively green for the phase under consideration,
X= the degree of saturation,
q= flow, vehicle per cycle.

3. PREVIOUS STUDIES

Many traffic improvement studies were performed in different locations of Baghdad city. Some of these studies used Highway Capacity Software (HCS-2000) and others used TRANSYT-7F programs to the evaluation process and provide the optimal signal timing data.

The following articles summarize some of these studies:

Amanat Baghdad, (1982), conducted Baghdad Comprehensive Transportation Study (BCTS) with the objective of the evaluation of traffic performance for the selected facilities in Baghdad city.

A roadway network has been recommended that attracts the major traffic movements to the primary road system, enabling public transport to benefit from the improved traffic conditions and restricting the use of local streets to local traffic. The recommended highway network consists of an inner freeway box (ring road 1) around and close to the Central Business District (CBD), an inner orbital route (ring road 2) of expressway standard, a middle orbital route (ring road 3) of freeway standard, a long-term outer orbital (ring road 4) of freeway standard.

Mankhi, 2002, investigated the influence of delay, running speed and the density of passenger in the bus, and the capacity of the route parameters on evaluating the overall routes and network levels of service. The data collection for the work was included two parts; the first was the questionnaire methods while the second was the field data collection. The study shows that each of the selected four individual service characteristics affects the level of service evaluation by different percentage according to their importance to the users.

Khader, 2003, analyzed the traffic pattern in the center of Al-Kadimiya and defined the traffic problems. The video recording was utilized to observe the volume of traffic and pedestrian. Data were abstracted and analyzed using Event, Excel, and STATISTICA programs. Furthermore, the TRAFFICQ program was used to test the proposed engineering design for the network.

Hilal, 2004, developed a computer program for determination of the signal cycle which minimizes the overall vehicle delay at isolated signal controlled intersection.

Al-Zaidy, 2005, studied the influence of socioeconomic factors on trip generation for Al-Hadar District at Al-Dora area at the south of Baghdad City. The study found that the most effective independent variable on trip generation for families are number of worker, number of students, type of vehicle and age group

4. STUDY AREA

Initially, the study area was categorized to include three main cases:

I. Interrupted traffic flow at signalized intersections due to heavy traffic volumes, for this case the following intersections are considered:
   - Boratha Mosque intersection.
   - Al-Shalchiya intersection.
   - Aden intersection.

II. Interrupted traffic flows at the arterial streets. Most of the arterials within the study area were analyzed.

III. Uninterrupted traffic flows at expressway segments. Al-Shemal expressway.

All the three study cases are within the municipality border of Al-Kadhimiya city.

Figs.1 to 4 illustrate the study area, while **Table 1** presents the adopted survey methods and the utilized equipment.

5. PEAK HOUR SELECTION

According to trip purpose, PCU (passenger car unit) travel times fluctuate throughout the day. Considerable differences occur during different periods of the day. Therefore, in video recording it was found often necessary to obtain the most significant periods of the day required to satisfy the study objectives. In this aspect, four periods were identified from (6:00 am to 6:00 pm) to determine

the peak period time. According to the recording processes, it has been clarified that the peak period is from 8:00 am to 9:00 am for intersections (Boratha Mosque and Shalchiya), while for Aden-intersection, the peak period was from 2:00 pm to 3:00 pm. **Tables 2** to **4** show the variation of traffic flow for the three intersections. These data are depicted in **Figs 5** to **7**.

6. OPERATION ANALYSIS OF EXISTING TRAFFIC FLOW (INTERSECTIONS)

The most common method to evaluate the performance of any traffic network is to simulate the existing traffic flow patterns along the area under study. **Tables 5** to **7** summarize the analysis of the intersections level of service under existing condition. It is obviously noticed from designated tables that the total delay for the most intersection under consideration is very high and the max (v/c) is greater than (1.0), furthermore, the level of service is (F) for all intersections.

7. ALTERNATIVES FOR IMPROVEMENT OF TRAFFIC PERFORMANCE (INTERSECTIONS)

After studying the performance of all intersections as mentioned previously for the existing condition, and in order to improve the traffic performance in the study area, the following improvement alternatives are introduced:

7.1 Alternative No.1 (Cycle Length Optimization)

To relieve the breakdown condition (level of service F), the optimization process is considered as the first improvement stage. HCS2000-Signals contains a signal timing estimation/optimization module called "SOAP2K". Currently, SOAP2K is capable of performing genetic algorithm optimization of cycle length and phase times. **Table 8** shows the best cycle length selected for each intersection. The selection of the best phasing time for each phase sequence for each approach depends on the traffic volume. **Tables 9** to **11** show the performance evaluation for all intersections under the first alternative. From the output results, it can be noticed that the measure of effectiveness ((v/c) ratio, total delay) are improved for all intersections. Although these improvements occur for all intersections, both of (Boratha Mosque and Al-Shalchiya) intersections still suffer from the high value of total delay time.

7.2 Alternative No.2 (Increasing the Number of Lanes)

This stage includes increasing the number of lanes on specified approaches to isolated intersections in order to increase the capacity of the approaches operating at oversaturation condition, and to provide better level of service. Therefore, one lane was added on approaches for each intersection according to the available area. **Tables 12** to **14** show the performance evaluation for all intersections. From the results obtained from the second improvement alternative, it can be noticed that a huge saving in measures of effectiveness, especially the total delay, is obtained for all intersections.

7.3 Alternative No.3 (Combination of the First Two Alternatives)

The third alternative is a combination of the first two improvements. This alternative includes selecting the best cycle length by timing optimization and increasing the number of lanes on the approaches. **Tables 15** to **17** summarize the results obtained from HCS-2000 program under this alternative. It can be noticed that the total delay is decreased for all intersections. It can also be noticed that the LOS for intersection 3 is upgraded to level C.

7.4 Alternative No.4 (Overpasses Construction)

Alternative No.4 is designed to include the construction of overpasses in the following intersections:

1. The overpass at Boratha Mosque intersection in EB and WB directions.
2. The overpass at Al-Shalchiya intersection in NB and SB directions along 14th July Street.

Consequently, for this alternative the phase sequences for the intersections mentioned above are changed as follows:

1. Boratha Mosque intersection is changed to 3-phase instead of a 4-phase operation.
2. Al-Shalchiya intersection is changed to 2-phase instead of a 3-phase operation.

It is important to note that the implementation of alternative No.3 is required in this stage, which includes selecting the best cycle length by timing optimization and increasing the number of lanes on the approaches.**Table 18** and **Table 19** show the performance evaluation of intersections 1 and 2 under alternative No.4. It can be noticed from these tables that a very high percentage of reduction in total delay at Boratha Mosque, and Al-Shalchiya intersections are obtained, and the LOS for these intersections is upgraded to level C and level B, respectively.

8. EVALUATION OF THE IMPROVEMENT ALTERNATIVES (INTERSECTIONS)

Table 20 summarizes the percent of saving in the measures of effectiveness for the four alternatives in comparison with results obtained from simulation of existing condition. According to Eq. (2).

$$\text{Saving, \%} = \frac{(\text{TD Existing} - \text{TD Alternative})}{\text{TD Existing}} \times 100 \qquad (2)$$

where:

TD = Total Delay for intersection.

Percentages of saving vary from one alternative to another. From **Table 20**, it can be concluded that alternative No.4 has the highest saving and benefit among other alternatives. **Figs. 8** to **10** show the percentage of saving for all intersections.

9. ANALYSIS OF URBAN STREETS WITHIN THE STUDY AREA

In this study, important arterials of the study area are analyzed and computations for LOS are performed by HCS-2000 program. **Table 21** summarizes the analysis of the arterials level of service under current condition.

10. URBAN STREETS LEVEL OF SERVICE UNDER FUTURE CONDITION

The future condition is represented by the annual growth rate of 3% during the next five to ten years. The analysis is carried out to identify the performance of the study area under these conditions.**Table 22** and **Table 23** summarize the results obtained from simulation of the existing condition of the studied area with a growth rate of (3%) in target years (2015) and (2020) respectively.

11. IMPROVEMENT ALTERNATIVES OF TRAFFIC PERFORMANCE (ARTERIALS)

In order to improve the traffic performance in the study area, the following improvement alternatives are introduced.

11.1 Alternative No.1 (Roadway Widening)

This alternative includes increasing the number of lanes which lead to increase the capacity of the arterials and to provide a better arterial level of service.**Table 24** shows the performance evaluation for all arterial streets under the first alternative.

11.2 Alternative No.2 (Modify Signals)

This alternative involves reconfiguring intersection in order to increase (g/C) ratio, where (g) is the duration of effective green for the approach and (C) is the cycle length for the intersections. The gained effect from changing (g/C) ratio on arterials performance is shown in **Table 25**, and it is indicating that high reduction in delay (greater saving) is achieved for all arterial accompanied by upgrading LOS for some arterials.

11.3 Alternative No.3 (Combination of the First Two Alternatives)

The third alternative is a combination of the first two improvements. This alternative includes widening roadway along with increasing (g/C). **Table 26** summarizes the results obtained from analysis operation. By observing this table, it can be noticed that the total delay is decreased for all arterial.

12. EVALUATION OF THE IMPROVEMENT ALTERNATIVE FOR ARTERIALS

Table 27 summarizes the percent of saving in the measures of effectiveness for the three alternatives in comparison with results obtained from simulation of the existing condition of the study area. Percentages of saving vary from one alternative to another. By observing **Table 27**, it can be concluded that Alternative No.3 has the highest saving and benefit among other alternatives. **Fig. 11** shows the percentage of saving for all arterials.

13. INTERSECTIONS AND ARTERIAL LOS UNDER FUTURE CONDITION

The future condition is represented by the annual growth rate of 3% during the next five to ten years and investigated for alternative No.4 in the intersection case. **Tables 28** to **31** summarize the percent of saving in the measures of effectiveness for alternative No.4 in comparison with results obtained from simulation of existing condition of the studied area with growth rate of (3%) in target years (2015) and (2020), respectively .

14. CONCLUSIONS

According to the results of this work, the following conclusions have been drawn:

1. For analyzed signalized intersections:

    a) The cycle time optimizations minimize the total delay in Boratha Mosque, Al-Shalchiya and Aden intersection by (3.5%, 16.1%, 18.45%) respectively. Furthermore, Aden intersection performs adequate LOS by optimizing cycle time only.
    b) Increasing the number of lanes (one lane added to each approach per intersection) will produce a significant saving in all measures of effectiveness, though reducing the existing total delay of Boratha Mosque, Al-Shalchiya and Aden intersection by (73.2%, 43.9%, 33.9%) respectively.

c) Increasing the number of lanes in conjunction with optimizing the cycle time will reduce the total delay by (73.4%, 58.8%, 38.0%) respectively.
d) The overpass construction is the best solution for traffic problem for both (Boratha Mosque Int.) and (Al-Shalchiya Int.) a high percentage of saving in delay will be obtained (34.8%, 16.4%) and LOS will be upgraded to LOS C and B respectively.

2. For analyzed arterial (Based on future condition):

a) Arterial (Al-Rabiaa, Boratha, Al-Damergi, 14 Ramadan, Al-Askareen, Mohammed Al-jwaad, Mohammed Al-Qasim, Al-Smoud, Al-Hasan, Al Tobchi and Al-Farazdak) shows adequate LOS performance in the future condition and no improvement needed for these arterials
b) Roadway widening which is adding one lane for each arterial per direction decreases the delay significantly for all arterials. Arterials (Al-Hamza, Zain Al-Abiden, Ibn Siena and Abid Al-Mohsin Al-Kadimi) will improve their LOS from F to LOS D, E, E, and E respectively.
c) Modifying Signal timing decreases the control delay for arterials. The delay in Arterials (Al-Hassain, Al-Hamza, Mosa Al-Kadhim, Zain Al-Abiden, Ibn Siena and Abid Al-Mohsin Al-Kadimi) will reduce by (19.1%, 30.0%, 23.8%, 31.9%, 22.9%, 51.0%) respectively.
d) Modifying Signal timing in conjunction with Roadway widening will upgrade the LOS for arterials (Al-Hamza, Zain Al-Abiden, Ibn Siena and Abid Al-Mohsin Al-Kadimi) from F to LOS of C, D, E, C, and C respectively.

15. RECOMMENDATION

1. For intersections

a) It is recommended to implement the cycle length optimization for all intersection in the study area.

b) It is recommended to implement the fourth alternative which is constructing overpasses for both (Boratha Mosque Int.) and (Al-Shalchiya Int.).

2. For arterials

a) It is recommend to perform wider questionnaire survey to include a sufficient area to cover on board arterials, through its important to mention that the results for arterials are based on volumes that the questionnaire survey covered only.

b) It is recommended to implement the third alternative which consists of a combination of roadway widening and modifying signal timing.

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NOMENCLATURE

MOEs= Measures of Effectiveness
d= the average delay per vehicle, sec,
C= cycle time, sec,
λ= proportion of the cycle time, which is effectively green for the phase under consideration,
X= the degree of saturation,
q= flow, vehicle per cycle.
BCTS= Baghdad Comprehensive Transportation Study
CBD= Central Business District
HCS= Highway Capacity Software
PCU= Passenger Car Unit
v/c= Volume/Capacity
LOS= Level of Service
TD = Total Delay for intersection

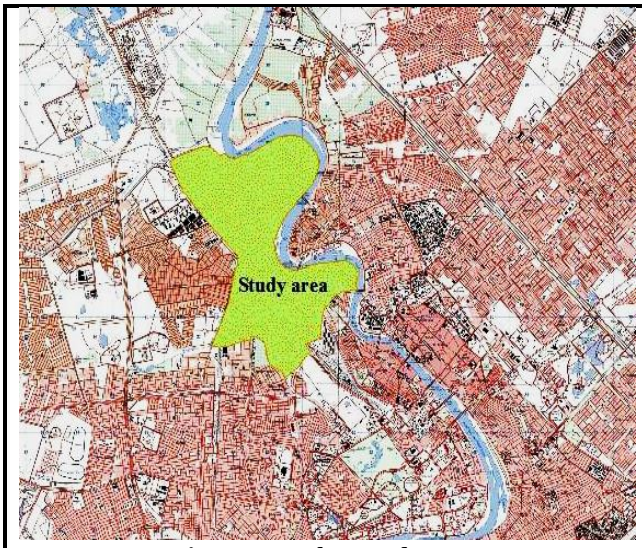

Figure 1. The study area

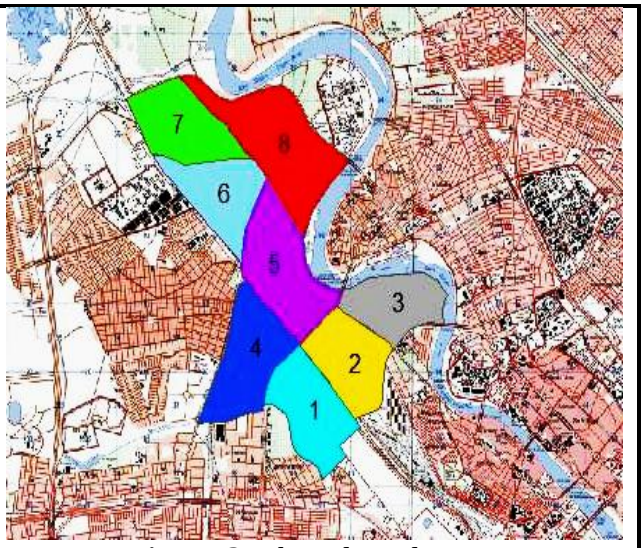

Figure 2. The selected zones

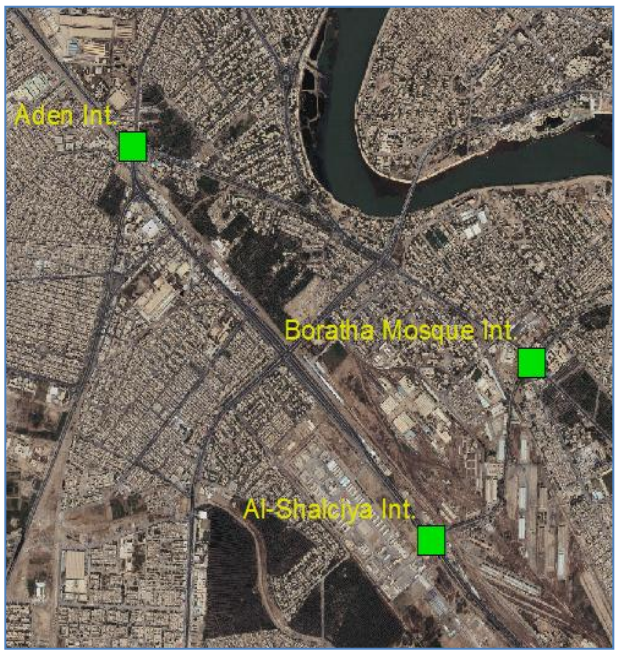

Figure 3. The intersections locations

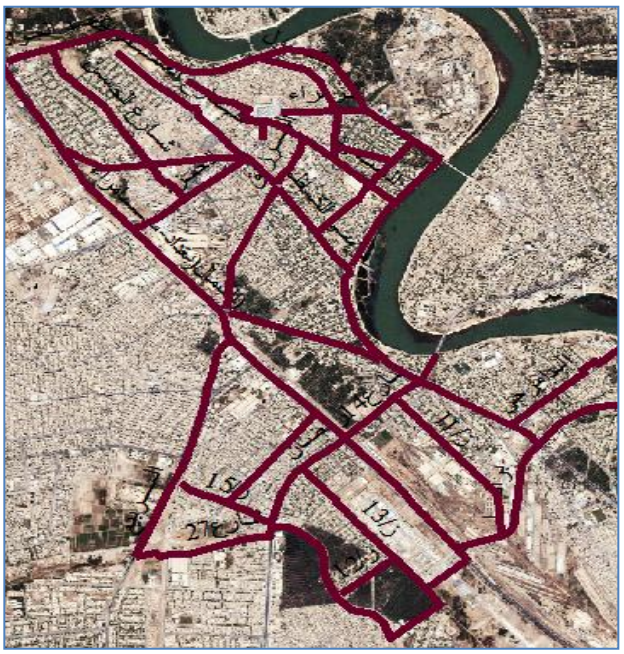

Figure 4. The arterial streets and highway in the study area

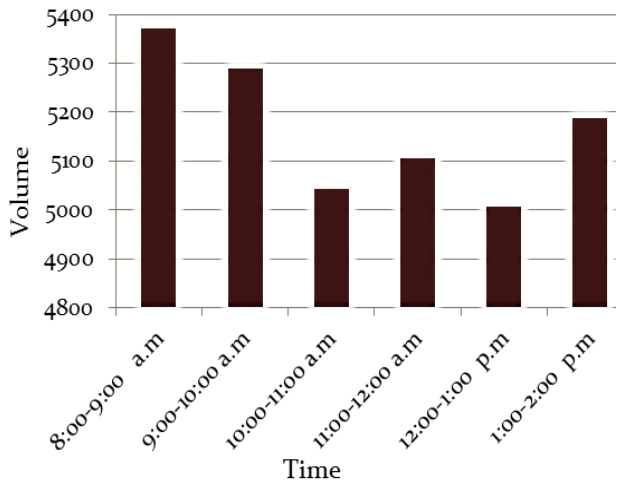

Figure 5. Variation of traffic flow at Boratha Mosque intersection (Int.1)

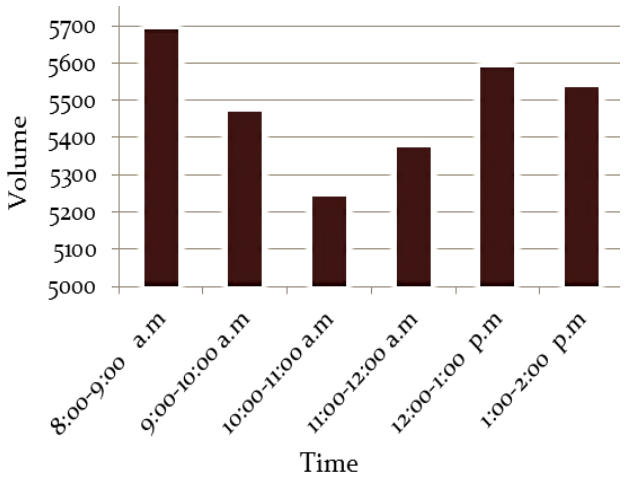

Figure 6. Variation of traffic flow at Al-Shalchiya intersection (Int.2)

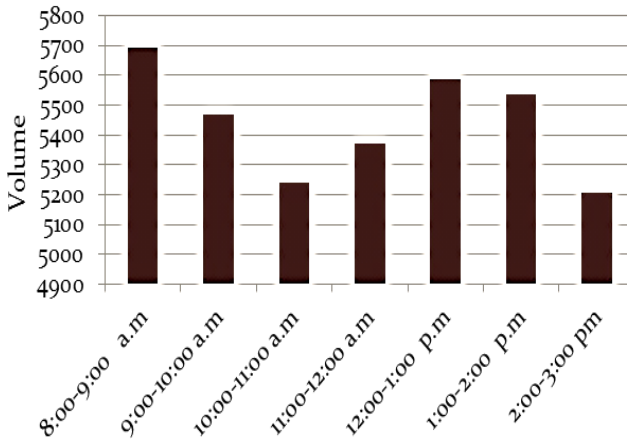

Figure 7. Variation of traffic flow at Aden intersection (Int.3)

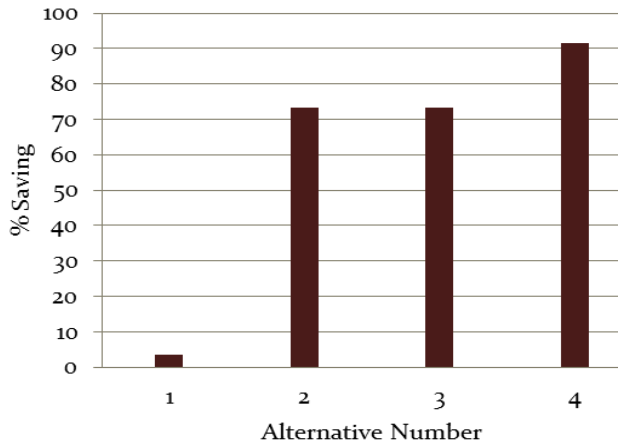

Figure 8. Saving in average delay for Boratha Mosque (Int.1)

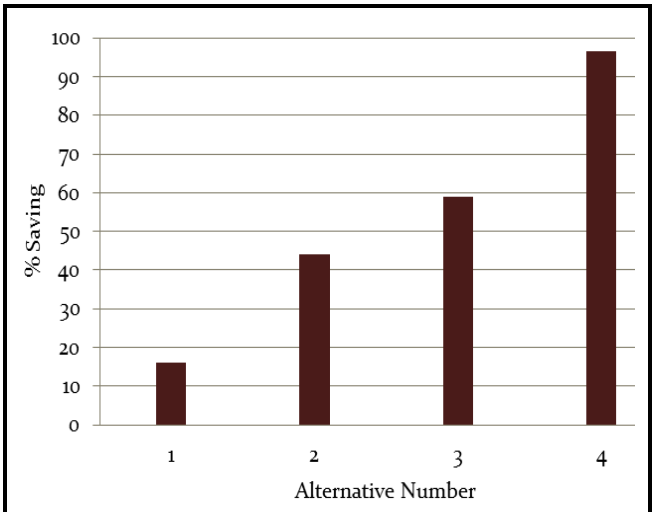

Figure 9. Saving in average delay for Al-Shalchiya (Int.2)

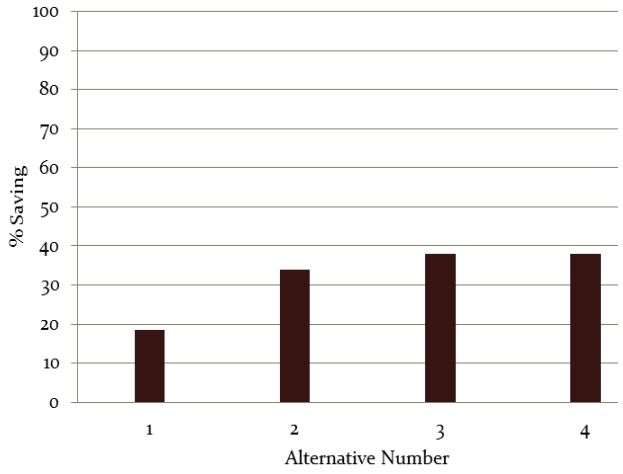

Figure 10. Saving in average delay for Aden (Int.3)

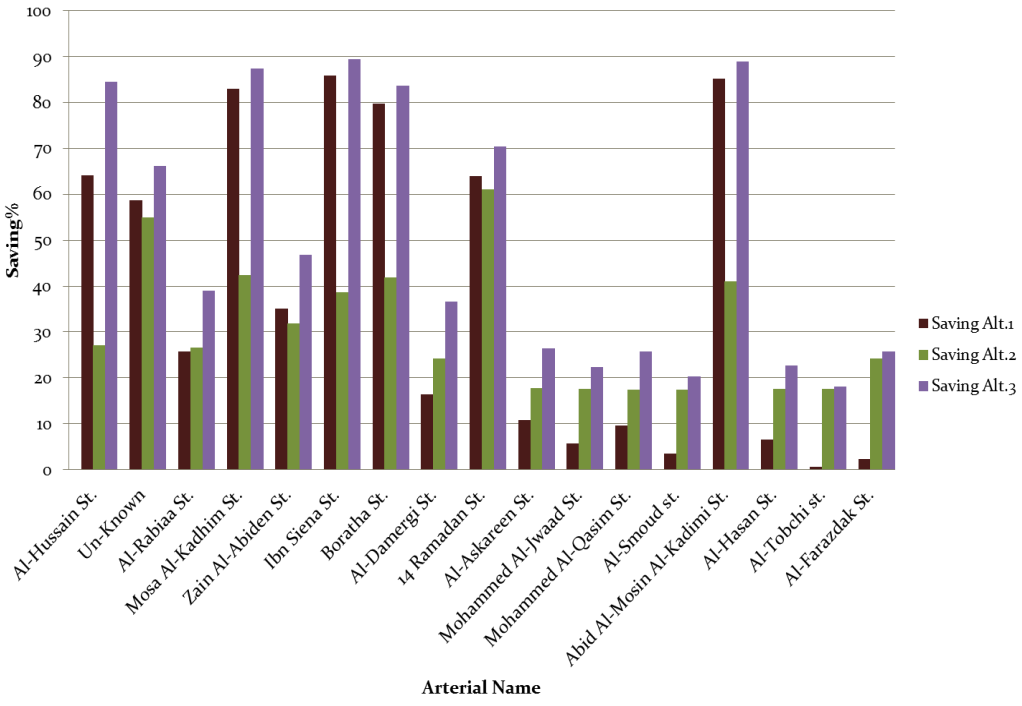

Figure 11. Saving in average delay for arterials under all alternatives

Table 1. Survey methods and equipment

Survey	Method	Equipment and personnel
Traffic volume (for junctions)	Video technique and manual count	Digital video camera and manual count
Traffic volume (for Road network)	Questionnaire	Two trained interviewer groups
Distance	GPS and manual	GIS program with internet connection, Baghdad aerial view digital picture and meters tape

Table 2. Variation of traffic flow at Boratha Mosque intersection (Int.1)

Duration	Volume (vph)
8:00-9:00 am	5371
9:00-10:00 am	5289
10:00-11:00 am	5044
11:00-12:00 am	5107
12:00-1:00 pm	5006
1:00-2:00 pm	5188
2:00-3:00 pm	5041

Table 3. Variation of traffic flow at Al-Shalchiya intersection (Int.2)

Duration	Volume (vph)
8:00-9:00 am	5691
9:00-10:00 am	5468
10:00-11:00 am	5240
11:00-12:00 am	5372
12:00-1:00 pm	5587
1:00-2:00 pm	5535
2:00-3:00 pm	5204

Table 4. Variation of traffic flow at Aden intersection (Int.3)

Duration	Volume (vph)
8:00-9:00 am	4210
9:00-10:00 am	4149
10:00-11:00 am	4056
11:00-12:00 am	4004
12:00-1:00 pm	4144
1:00-2:00 pm	4282
2:00-3:00 pm	4361

Table 5. Performance evaluation of Boratha Mosque intersection (Int.1), current condition

Lane Mov.		Vol. (vph)	c (vph)	g/C	v/c	d (sec)	LOS	App. d. (sec)	App. LOS	Int. d (sec)	Int. LOS
EB	L	271	280	0.22	1.08	120.1	F	138.6	F	408.9	F
	Th	928	863	0.22	1.19	143.9	F				
WB	L	608	273	0.21	2.32	650.3	F	388.7	F		
	Th	514	546	0.21	0.98	79.1	E				
NB	L	561	248	0.17	2.60	779.5	F	551.1	F		
	Th	725	488	0.17	1.71	374.3	F				
SB	L	653	333	0.26	2.18	583.4	F	496.9	F		
	Th	1120	660	0.26	1.88	446.4	F				

Table 6. Performance evaluation of Al-Shalchiya intersection (Int.2), current condition

Lane Mov.		Vol. (vph)	c (vph)	g/C	v/c	d (sec)	LOS	App. d. (sec)	App. LOS	Int. d (sec)	Int. LOS
EB		-	-	-	-	-	-	-	-	461.1	F
WB	L	932	1023	0.27	1.01	57.8	E	57.8	E		
	Th	-	-	-	-	-	-				
NB	L	-	-	-	-	-	-	372.8	F		
	Th	2771	1632	0.33	1.77	372.8	F				
SB	L	1908	772	0.32	2.69	787.6	F	787.6	F		
	Th	-	-	-	-	-	-				

Table 7. Performance evaluation of Aden intersection (Int.3), current condition

Lane Mov.		Vol. (vph)	c (vph)	g/C	v/c	d (sec)	LOS	App. d. (sec)	App. LOS	Int. d (sec)	Int. LOS
EB	L	185	670	0.19	0.28	40.2	D	39.7	D	90.2	F
	Th	197	951	0.19	0.21	39.2	D				
WB	L	263	902	0.2	0.21	39.4	D	57.8	E		
	Th	702	702	0.2	1	79.5	E				
NB	L	1533	1256	0.26	1.22	148.6	F	372.8	F		
	Th	529	1816	0.26	0.29	33.9	C				
SB	L	-	-	-	-	-	-	787.6	E		
	Th	615	705	0.2	0.87	58.1	E				

Table 8. The existing and the best cycle length selected with total delay for intersections

Intersections	The Existing Cycle Length (sec)	The Existing Total Delay (sec/veh)	The Best Cycle Length Selected (sec)	Total Delay after Timing Optimization (sec/veh)
1	115	408.9	120	394.6
2	73	461.9	90	387.6
3	114.0	90.2	83	29.6

Table 9. Performance evaluation of Boratha Mosque intersection (Int.1), alternative (1)

Lane Mov.		Vol. (vph)	c (vph)	g/C	v/c	d (sec)	LOS	App. d. (sec)	App. LOS	Int. d (sec)	Int. LOS
EB	**L**	271	226	0.17	1.33	225.9	F	263.7	F	394.6	F
	Th	928	695	0.17	1.48	274.7	F				
WB	**L**	608	259	0.2	2.44	709.5	F	429	F		
	Th	514	517	0.2	1.03	97	F				
NB	**L**	561	355	0.25	1.82	423.6	F	266.6	F		
	Th	725	699	0.25	1.19	145.1	F				
SB	**L**	653	312	0.24	2.33	652.4	F	558.6	F		
	Th	1120	620	0.24	2.01	503.9	F				

Table 10. Performance evaluation of Al-Shalchiya intersection (Int.2), alternative (1)

Lane Mov.		Vol. (vph)	c (vph)	g/C	v/c	d (sec)	LOS	App. d. (sec)	App. LOS	Int. d (sec)	Int. LOS
EB		-	-	-	-	-	-	-	-	387.6	F
WB	**L**	932	540	0.14	1.92	458.7	F	458.7	F		
	Th	-	-	-	-	-	-				
NB	**L**	-	-	-	-	-	-	210.7	F		
	Th	2771	2057	0.41	1.4	210.7	F				
SB	**L**	1908	918	0.37	2.26	598.3	F	598.3	F		
	Th	-	-	-	-	-	-				

Table 11. Performance evaluation of Aden intersection (Int.3), alternative (1)

Lane Mov.		Vol. (vph)	c (vph)	g/C	v/c	d (sec)	LOS	App. d. (sec)	App. LOS	Int. d (sec)	Int. LOS
EB	L	185	427	0.12	0.43	36.9	D	13.7	B	29.6	C
	Th	197	606	0.12	0.33	34.7	C				
WB	L	263	953	0.21	0.28	28	C	46.2	D		
	Th	702	742	0.21	0.95	54.4	D				
NB	L	1533	1760	0.37	0.87	39.6	C	25.5	C		
	Th	529	2544	0.37	0.21	18.1	B				
SB	L	-	-	-	-	-	-	41.9	D		
	Th	615	694	0.2	0.89	47.8	D				

Table 12. Performance evaluation of Boratha Mosque intersection (Int.1), alternative (2)

Lane Mov.		Vol. (vph)	c (vph)	g/C	v/c	d (sec)	LOS	App. d. (sec)	App. LOS	Int. d (sec)	Int. LOS
EB	L	271	437	0.17	0.69	53.1	D	99.7	F	109.7	F
	Th	928	926	0.17	1.11	113.3	F				
WB	L	608	479	0.19	1.32	205.4	F	134.9	F		
	Th	514	710	0.19	0.75	51.4	D				
NB	L	561	546	0.2	1.18	145.4	F	114.9	F		
	Th	725	795	0.2	1.05	91.3	F				
SB	L	653	742	0.3	0.98	68.1	E	97.5	F		
	Th	1120	1091	0.3	1.14	114.7	F				

Table 13. Performance evaluation of Al-Shalchiya intersection (Int.2), alternative (2)

Lane Mov.		Vol. (vph)	c (vph)	g/C	v/c	d (sec)	LOS	App. d. (sec)	App. LOS	Int. d (sec)	Int. LOS
EB		-	-	-	-	-	-	-	-	259.1	F
WB	L	932	1365	0.27	0.76	28.3	C	28.3	C		
	Th	-	-	-	-	-	-				
NB	L	-	-	-	-	-	-	214.1	F		
	Th	2771	2040	0.33	1.41	214.1	F				
SB	L	1908	1087	0.32	1.91	437.1	F	437.1	F		
	Th	-	-	-	-	-	-				

Table 14. Performance evaluation of Aden intersection (Int.3), alternative (2)

Lane Mov.		Vol. (vph)	c (vph)	g/C	v/c	d (sec)	LOS	App. d. (sec)	App. LOS	Int. d (sec)	Int. LOS
EB	L	185	553	0.11	0.33	37.6	D	14.4	B	24.0	C
	Th	197	560	0.11	0.35	37.7	D				
WB	L	263	1016	0.23	0.26	28.5	C	31.2	C		
	Th	702	1131	0.23	0.62	33.2	C				
NB	L	1533	2170	0.34	0.71	27.1	C	23.8	C		
	Th	529	2353	0.34	0.22	20.9	C				
SB	L	-	-	-	-	-	-	27.8	C		
	Th	615	1136	0.23	0.54	31.8	C				

Table 15. Performance evaluation of Boratha Mosque intersection (Int.1), alternative (3)

Lane Mov.		Vol. (vph)	c (vph)	g/C	v/c	d (sec)	LOS	App. d. (sec)	App. LOS	Int. d (sec)	Int. LOS
EB	L	271	444	0.18	0.68	54.2	D	96.5	F	108.7	F
	Th	928	940	0.18	1.1	108.8	F				
WB	L	608	470	0.19	1.35	218.6	F	143.4	F		
	Th	514	696	0.19	0.77	54.4	D				
NB	L	561	549	0.2	1.17	144.7	F	114.8	F		
	Th	725	799	0.2	1.04	91.6	F				
SB	L	653	757	0.31	0.96	65	E	91.8	F		
	Th	1120	1112	0.31	1.12	107.5	F				

Table 16. Performance evaluation of Al-Shalchiya intersection (Int.2), alternative (3)

Lane Mov.		Vol. (vph)	c (vph)	g/C	v/c	d (sec)	LOS	App. d. (sec)	App. LOS	Int. d (sec)	Int. LOS
EB		-	-	-	-	-	-	-	-	190.4	F
WB	L	932	735	0.15	1.41	226.5	F	226.5	F		
	Th	-	-	-	-	-	-				
NB	L	-	-	-	-	-	-	102.1	F		
	Th	2771	2482	0.4	1.16	102.1	F				
SB	L	1908	1302	0.38	1.59	295.4	F	295.4	F		
	Th	-	-	-	-	-	-				

Table 17. Performance evaluation of Aden intersection (Int.3), alternative (3)

Lane Mov.		Vol. (vph)	c (vph)	g/C	v/c	d (sec)	LOS	App. d. (sec)	App. LOS	Int. d (sec)	Int. LOS
EB	L	185	596	0.12	0.31	35.4	D	13.6	B	22.5	C
	Th	197	603	0.12	0.33	35.5	D				
WB	L	263	994	0.22	0.26	28	C	30.7	C		
	Th	702	1107	0.22	0.63	32.7	C				
NB	L	1533	2531	0.4	0.61	21.4	C	18.9	B		
	Th	529	2744	0.4	0.19	16.9	B				
SB	L	-	-	-	-	-	-	35.2	D		
	Th	615	817	0.16	0.75	40.3	D				

Table 18. Performance evaluation of Boratha Mosque intersection (Int.1), alternative (4)

Lane Mov.		Vol. (vph)	c (vph)	g/C	v/c	d (sec)	LOS	App. d. (sec)	App. LOS	Int. d (sec)	Int. LOS
EB	L	271	812	0.23	0.37	25.6	C	25.6	C	34.8	C
	Th	-	-	-	-	-	-				
WB	L	608	824	0.23	0.77	33.8	C	33.8	C		
	Th	-	-	-	-	-	-				
NB	L	561	679	0.25	0.93	49.1	D	41.4	D		
	Th	725	989	0.25	0.84	35.6	D				
SB	L	653	901	0.36	0.81	29.1	C	31.7	C		
	Th	1120	1368	0.36	0.91	33.2	C				

Table 19. Performance evaluation of Al-Shalchiya intersection (Int.2), alternative (4)

Lane Mov.		Vol. (vph)	c (vph)	g/C	v/c	d (sec)	LOS	App. d. (sec)	App. LOS	Int. d (sec)	Int. LOS
EB		-	-	-	-	-	-	-	-	16.4	B
WB	L	932	1219	0.24	0.85	24.4	C	24.4	C		
	Th	-	-	-	-	-	-				
NB		-	-	-	-	-	-	-	-		
SB	L	1908	2312	0.67	0.9	12.4	B	12.4	B		
	Th	-	-	-	-	-	-				

Table 20. Comparisons between all improvements and existing conditions

		Int. 1	Int. 2	Int. 3
Existing Condition	**T. D (sec/veh)**	408.9	461.9	90.2
	Int. LOS	F	F	F
Alternative (1)	**T. D (sec/veh)**	394.6	387.6	29.6
	Int. LOS	F	F	C
	Saving %	3.5	16	67
Alternative (2)	**T. D (sec/veh)**	109.7	259.1	24.0
	Int. LOS	F	F	C
	Saving %	73.2	44	73.3
Alternative (3)	**T. D (sec/veh)**	108.7	190.4	22.5
	Int. LOS	F	F	C
	Saving %	73.4	59	75.1
Alternative (4)	**T. D (sec/veh)**	34.8	16.4	22.5
	Int. LOS	C	B	C
	Saving %	91.5	96.5	75.1

Table 21. Performance of arterials under existing conditions

Arterial Name	Volume	Number of lanes	Presence of median	Section Length (Km)	LOS
Al-Hussain St.	5399	6	No	1.302	F
Al-Hamza	3955	6	Yes	1.169	D
Al-Rabiaa St.	4935	8	Yes	2.284	C
Mosa Al-Kadhim St.	4673	6	Yes	3.538	E
Zain Al-Abiden St.	3520	6	No	1.204	E
Ibn Siena St.	3219	4	Yes	1.512	F
Boratha St.	4611	6	Yes	2.269	E
Al-Damergi St.	1454	4	No	1.227	B
14 Ramadan St.	5416	8	Yes	2.206	D
Al-Askareen St.	2277	6	Yes	1.896	C
Mohammed Al-Jwaad St.	2130	8	Yes	4.273	B
Mohammed Al-Qasim St.	3390	8	Yes	1.344	C
Al-Smoud st.	862	6	Yes	2.268	C
Abid Al-Mohsin Al-Kadimi St.	3711	4	No	1.291	F
Al-Hasan St.	2327	8	Yes	1.845	C
Al-Tobchi st.	108	6	Yes	1.127	D
Al-Farazdak St.	75	2	No	0.502	D

Table 22. Future performance of arterial, target year (2015) & r = 3%.

Arterial Name	Volume	Number of lanes	Presence of median	Section Length (Km)	LOS
Al-Hussain St.	6263	6	N	1.302	F
Al-Hamza	4587	6	Yes	1.169	E
Al-Rabiaa St.	5725	8	Yes	2.284	D
Mosa Al-Kadhim St.	5421	6	Yes	3.538	F
Zain Al-Abiden St.	4083	6	N	1.204	F
Ibn Siena St.	3734	4	Yes	1.512	F
Boratha St.	5349	6	Yes	2.269	E
Al-Damergi St.	1686	4	No	1.227	B
14 Ramadan St.	6282	8	Yes	2.206	D
Al-Askareen St.	2641	6	Yes	1.896	C
Mohammed Al-Jwaad St.	2471	8	Yes	4.273	B
Mohammed Al-Qasim St.	3932	8	Yes	1.344	D
Al-Smoud st.	1000	6	Yes	2.268	C
Abid Al-Mohsin Al-Kadimi St.	4304	4	No	1.291	F
Al-Hasan St.	2699	8	Yes	1.845	C
Al-Tobchi st.	125	6	Yes	1.127	D
Al-Farazdak St.	87	2	No	0.502	D

Table 23. Future performance of arterial, target year (2020) & r = 3%.

Arterial Name	Volume	Number of lanes	Presence of median	Section Length (Km)	LOS
Al-Hussain St.	7235	6	N	1.302	F
Al-Hamza	5299	6	Yes	1.169	F
Al-Rabiaa St.	6613	8	Yes	2.284	D
Mosa Al-Kadhim St.	6262	6	Yes	3.538	F
Zain Al-Abiden St.	4717	6	N	1.204	F
Ibn Siena St.	4314	4	Yes	1.512	F
Boratha St.	6179	6	Yes	2.269	E
Al-Damergi St.	1948	4	No	1.227	C
14 Ramadan St.	7257	8	Yes	2.206	E
Al-Askareen St.	3051	6	Yes	1.896	C
Mohammed Al-Jwaad St.	2855	8	Yes	4.273	B
Mohammed Al-Qasim St.	4542	8	Yes	1.344	D
Al-Smoud st.	1155	6	Yes	2.268	C
Abid Al-Mohsin Al-Kadimi St.	4972	4	No	1.291	F
Al-Hasan St.	3118	8	Yes	1.845	C
Al-Tobchi st.	145	6	Yes	1.127	D
Al-Farazdak St.	101	2	No	0.502	E

Table 24. Arterials LOS and controlling delay, alternative (1)

Arterial Name	LOS	Control Delay
Al-Hussain St.	D	98.0
Al-Hamza	C	25.1
Al-Rabiaa St.	B	24.8
Mosa Al-Kadhim St.	B	24.5
Zain Al-Abiden St.	E	24.3
Ibn Siena St.	C	23.1
Boratha St.	B	28.4
Al-Damergi St.	B	16.2
14 Ramadan St.	B	26.5
Al-Askareen St.	C	19.6
Mohammed Al-Jwaad St.	B	18.2
Mohammed Al-Qasim St.	C	20.7
Al-Smoud st.	C	16.6
Abid Al-Mohsin Al-Kadimi St.	C	22.4
Al-Hasan St.	C	18.5
Al-Tobchi st.	D	15.3
Al-Farazdak St.	D	12.9

Table 25. Arterials LOS and controlling delay, alternative (2)

Arterial Name	LOS	Control Delay
Al-Hussain St.	F	199.0
Al-Hamza	C	27.4
Al-Rabiaa St.	B	24.5
Mosa Al-Kadhim St.	D	82.5
Zain Al-Abiden St.	E	25.5
Ibn Siena St.	E	99.7
Boratha St.	D	81.3
Al-Damergi St.	B	14.7
14 Ramadan St.	B	28.6
Al-Askareen St.	B	18.1
Mohammed Al-Jwaad St.	B	15.9
Mohammed Al-Qasim St.	C	18.9
Al-Smoud st.	C	14.2
Abid Al-Mohsin Al-Kadimi St.	C	88.4
Al-Hasan St.	B	16.3
Al-Tobchi st.	D	12.7
Al-Farazdak St.	C	10.0

Table 26. Arterials LOS and controlling delay, alternative (3)

Arterial Name	LOS	Control Delay
Al-Hussain St.	C	42.4
Al-Hamza	B	20.6
Al-Rabiaa St.	B	20.4
Mosa Al-Kadhim St.	B	18.2
Zain Al-Abiden St.	D	19.9
Ibn Siena St.	B	17.3
Boratha St.	B	23.0
Al-Damergi St.	B	12.3
14 Ramadan St.	B	21.7
Al-Askareen St.	B	16.2
Mohammed Al-Jwaad St.	B	15.0
Mohammed Al-Qasim St.	C	17.0
Al-Smoud st.	C	13.7
Abid Al-Mohsin Al-Kadimi St.	C	16.8
Al-Hasan St.	B	15.3
Al-Tobchi st.	D	12.6
Al-Farazdak St.	C	9.8

Table 27. Comparisons between all improvements and existing conditions

Arterial Name	Existing Condition		Alternative 1			Alternative 2			Alternative 3		
	LOS	C.D.	LOS	C. D.	Saving%	LOS	C. D.	Saving%	LOS	C. D.	Saving%
Al-Hussain St.	F	272.8	D	98.0	64.1	F	199.0	27.1	C	42.4	84.5
Al-Hamza	D	60.8	C	25.1	58.7	C	27.4	54.9	B	20.6	66.1
Al-Rabiaa St.	C	33.4	B	24.8	25.7	B	24.5	26.6	B	20.4	38.9
Mosa Al-Kadhim St.	E	143.2	B	24.5	82.9	D	82.5	42.4	B	18.2	87.3
Zain Al-Abiden St.	E	37.4	E	24.3	35.0	E	25.5	31.8	D	19.9	46.8
Ibn Siena St.	F	162.4	C	23.1	85.8	E	99.7	38.6	B	17.3	89.3
Boratha St.	E	139.9	B	28.4	79.7	D	81.3	41.9	B	23.0	83.6
Al-Damergi	B	19.4	B	16.2	16.5	B	14.7	24.2	B	12.3	36.6
14Ramadan	D	73.4	B	26.5	63.9	B	28.6	61.0	B	21.7	70.4
AlAskareen St.	C	22.0	C	19.6	10.9	B	18.1	17.7	B	16.2	26.4
Mohammed Al-Jwaad	B	19.3	B	18.2	5.7	B	15.9	17.6	B	15.0	22.3
Mohammed Al-Qasim	C	22.9	C	20.7	9.6	C	18.9	17.5	C	17.0	25.8
Al-Smoud	C	17.2	C	16.6	3.5	C	14.2	17.4	C	13.7	20.3
Abid Al-Mohsin Al-Kadimi St.	F	150.0	C	22.4	85.1	C	88.4	41.1	C	16.8	88.8
Al-Hasan St.	C	19.8	C	18.5	6.6	B	16.3	17.7	B	15.3	22.7
Al-Tobchi st.	D	15.4	D	15.3	0.6	D	12.7	17.5	D	12.6	18.2
Al-Farazdak	D	13.2	D	12.9	2.3	C	10.0	24.2	C	9.8	25.8

Table 28. Comparative analysis of MOEs between the existing condition and the alternative no.4 at all intersections, target year (2015) & r = 3%.

	EXISTING CONDITION		ALTERNATIVE (4)		SAVING%
INTERSECTIONS	T.D (sec/veh)	LOS	T.D (sec/veh)	LOS	
1	408.9	F	54.9	D	86.6
2	461.9	F	38.7	D	91.6
3	60.0	E	21.3	C	64.0

Table 29. Comparative analysis of MOEs between the existing condition and the alternative no.4 at all intersections, target year (2020) & r = 3%.

	EXISTING CONDITION		ALTERNATIVE (4)		SAVING%
INTERSECTIONS	T.D (sec/veh)	LOS	T.D (sec/veh)	LOS	
1	408.9	F	103.9	F	74.6
2	461.9	F	98.7	F	78.6
3	98	F	32.3	C	67

Table 30. Comparisons between all improvements and existing conditions, target year (2015) & r = 3%

Arterial Name	Existing Condition		Alternative 1			Alternative 2			Alternative 3		
	LOS	C.D.	LOS	C. D.	Saving%	LOS	C. D.	Saving%	LOS	C. D.	Saving%
Al-Hussain St.	F	384.6	F	181.7	52.8	F	299.6	22.1	E	117.0	69.6
Al-Hamza	E	137.1	C	28.2	79.4	D	78.9	42.5	B	22.9	83.3
Al-Rabiaa St.	D	101.4	B	27.8	72.6	C	47.2	53.5	B	22.6	77.7
Mosa Al-Kadhim St.	F	234.1	D	69.2	70.4	F	164.1	29.9	B	22.9	90.2
Zain Al-Abiden St.	F	102.6	E	26.9	73.8	F	52.4	48.9	D	22.0	78.6
Ibn Siena St.	F	256.2	C	32.4	87.4	F	184.1	28.1	C	19.9	92.2
Boratha St.	E	225.5	C	67.4	70.1	E	162.2	28.1	B	27.5	87.8
Al-Damergi	B	21.2	B	17.0	19.8	B	16.0	24.5	B	12.9	39.2
14Ramadan	D	152.1	C	39.0	74.4	D	92.3	39.3	B	24.6	83.8
AlAskareen St.	C	23.7	C	20.6	13.1	C	19.5	17.7	B	17.1	27.8
Mohammed Al-Jwaad	B	20.1	B	18.8	6.5	B	16.6	17.4	B	15.5	22.9
Mohammed Al-Qasim	D	25.0	C	21.9	12.4	C	20.5	18.0	C	18.1	27.6
Al-Smoud	C	17.6	C	16.8	4.5	C	14.5	17.6	C	13.9	21.0
Abid Al-Mohsin Al-Kadimi St.	F	409.3	C	27.3	93.3	F	171.0	58.2	C	19.1	95.3
Al-Hasan St.	C	20.8	C	15.3	26.4	B	17.1	17.8	B	15.9	23.6
Al-Tobchi st.	D	15.4	D	15.3	0.6	D	12.7	17.5	D	12.7	17.5
Al-Farazdak	D	13.3	D	12.9	3.0	C	10.1	24.1	C	9.8	26.3

Table 31. Comparisons between all improvements and existing conditions, target year (2020) & r = 3%

Arterial Name	Existing Condition		Alternative 1			Alternative 2			Alternative 3		
	LOS	C.D.	LOS	C. D.	Saving%	LOS	C. D.	Saving%	LOS	C. D.	Saving%
Al-Hussain St.	F	510.7	F	276.2	45.9	F	413.0	19.1	F	202.0	60.4
Al-Hamza	F	223.8	D	62.8	71.9	F	156.6	30.0	C	26.9	88.0
Al-Rabiaa St.	D	182.4	C	62.0	66.0	E	119.4	34.5	B	26.4	85.5
Mosa Al-Kadhim St.	F	336.5	F	145.9	56.6	F	256.4	23.8	D	84.9	74.8
Zain Al-Abiden St.	F	184.3	E	38.5	79.1	F	125.5	31.9	E	25.0	86.4
Ibn Siena St.	F	362.4	E	99.5	72.5	F	279.4	22.9	C	43.9	87.9
Boratha St.	E	284.8	E	142.8	49.9	F	253.1	11.1	D	83.9	70.5
Al-Damergi	C	27.5	B	17.9	34.9	B	17.7	35.6	B	13.6	50.5
14Ramadan	E	241.2	E	108.7	54.9	E	172.3	28.6	C	53.4	77.9
AlAskareen St.	C	26.0	C	21.8	16.2	C	21.3	18.1	B	18.0	30.8
Mohammed Al-Jwaad	B	21.2	B	19.5	8.0	B	17.5	17.5	B	16.1	24.1
Mohammed Al-Qasim	D	27.9	D	23.6	15.4	C	22.7	18.6	C	19.4	30.5
Al-Smoud	C	18.0	C	17.1	5.0	C	14.9	17.2	C	14.1	21.7
Abid Al-Mohsin Al-Kadimi St.	F	539.1	E	88.5	83.6	F	264.3	51.0	C	34.4	93.6
Al-Hasan St.	C	22.0	C	20.1	8.6	C	18.1	17.7	B	16.6	24.5
Al-Tobchi st.	D	15.4	D	15.3	0.6	D	12.8	16.9	D	12.7	17.5
Al-Farazdak	E	13.4	D	13.0	3.0	C	10.2	23.9	C	9.8	26.9