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Improvement of Traffic Operation in Congested Signalized Intersections in Baghdad City

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Abstract

Intersections are usually considered as the critical points within the network and the evaluation of their performance provides valuable understanding and useful indication about the performance of the system. The capacity of signalized intersection is of more significant because such intersections often control the ability of the city streets to accommodate traffic. In Baghdad, most of the signalized intersections are congested and operate in LOS E or F. Accordingly, the objective of the present study is to improve the performance operation of two signalized intersections by investigating the proper alternatives to enhance the traffic capacity of the mentioned facilities. To achieve this objective, Maysaloon and AlBayda'a signalized intersection in Baghdad city were selected. Both of them are located in an area of heavy traffic volume since there are many attraction locations close to the study area.

The required data was collected manually by special team using the necessary survey equipment suitable for the study purpose. The analysis and evaluation throughout the study are performed by using Highway Capacity Software (HCS2000) program package, in order to identify the level of service for the studied intersections.

The results of this study revealed the selected traffic facility currently undergoes serious degradation causing breakdown conditions. Thus, urgent considerations must be given regarding the upgrading in the LOS by suggesting many alternatives. It is found that the best suitable one which is recommended to be executed, is to construct a flyover that connects Maysaloon square with AlBayda'a square towards Dorah expressway by consider the proposed geometrical design and the required number of lanes.

الخلاصــــــة
تعتبر التقاطعات عادة من النقاط الحرجة في شبكة الطرق، وان تقيم أداء هذه التقاطعات يمكن أن يوفر انطباعاً جيداً عن أداء الشبكة بشكل عام. إن الطاقة الاستيعابية للتقاطع هي الأكثر أهمية نظراً لان غالبية هذه التقاطعات هي المسيطرة على قابلية الشوارع في المدينة على استيعاب الحجوم المرورية. إن معظم التقاطعات الضوئية في بغداد تعاني من اختناقات مرورية وتعمل بمستوى خدمة E أو F. وتبعاً لذلك فان الهدف من الدراسة الحالية هو تطوير الأداء التشغيلي لتقاطعين عن طريق اختيار البدائل المناسبة وذلك بتعزيز الطاقة الاستيعابية لكلا التقاطعين. وللحصول على هذا الهدف فلقد تم اختيار تقاطعي ميسلون والبيضاء الواقعين في مدينة بغداد والتي تمتاز بحجوم مرورية عالية نظراً لوجود مناطق جذب كثيرة بالقرب من هذين التقاطعين.

لقد تم جمع البيانات من قبل فريق متخصص وباستخدام الأجهزة الملائمة لهذا الغرض. ومن ثم تم استخدام برنامج حاسوبي متطور (HCS 2000) لإيجاد مستوى الخدمة في هذه التقاطعات.

لقد بينت الدراسة بان التقاطعين المذكورين أنفاً تعاني من مشاكل حقيقية سببت تدني مستوى الأداء وكونت حالة من الاضطراب المروري لذلك تم وضع عدة بدائل لتحسين مستوى الخدمة وان أفضل هذه البدائل التي يوصى بتنفيذها هو إنشاء مجسر يربط تقاطع ميسلون مع تقاطع البيضاء باتجاه طريق الدورة السريع مع الأخذ بنظر الاعتبار التصميم الهندسي المقترح وأعداد الممرات المطلوبة.

1. Introduction

Intersections in the urban highway network have a significant effect on the operation and performance of the traffic system. There are two broad categories of intersections namely at Proceedings of the Eastern Asia Society for Transportation Studies, grade and grade separated. The traffic flow at level intersection may be uncontrolled, priority type or controlled. At the controlled intersections different directions of flow share the same road space and flow is segregated in terms of time. Due to sharing of the same space (in terms of time) by different directions of flow the traffic moves like stop and go situation [1]. Three measures of effectiveness are commonly used to evaluate signalized intersection operations: Capacity and volume-to-capacity ratio, delay, and queue [2].

Capacity is represented by the maximum rate at which vehicles can pass through a given point in an hour under prevailing conditions; it is often estimated based on assumed values for saturation flow. Capacity accounts for roadway conditions such as the number and width of lanes, grades, and lane use allocations, as well as signalization conditions [3]. Under the HCM 2000 procedure, intersection capacity is measured for critical lane groups (those lane groups that require the most amount of green time). Intersection volume-to-capacity ratios are based on critical lane groups; noncritical lane groups do not constrain the operations of a traffic signal. The v/c ratio, also referred to as degree of saturation, represents the sufficiency of an intersection to accommodate the vehicular demand. A v/c ratio less than 0.85 generally indicate that adequate capacity is available and vehicles are not expected to experience significant queues and delays. As the v/c ratio approaches 1.0, traffic flow may become unstable, and delay and queuing conditions may occur. Once the demand exceeds the capacity (a v/c ratio greater than 1.0), traffic flow is unstable and excessive delay and queuing is expected. Under these conditions, vehicles may require more than one signal cycle to pass through the intersection (known as a cycle failure).

For design purposes, a v/c ratio between 0.85 and 0.95 generally is used for the peak hour of the horizon year (generally 20 years out) [2].

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 [4] .

The average control delay per vehicle in HCM2000 is:

$$\mathbf{d = d_1 f_p + d_2 + d_3} \quad \text{.......... (1)}$$

where:

d_1: is uniform control delay ($d_1 \equiv d_u$),

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:

$$\mathbf{d2 = 900T\,(X - 1 + ((X - 1)^2 + 8kIX/cT)^{0.5})} \quad \text{.......... (2)}$$

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 [5].

Level of service is a measure by which transportation planners determine the quality of service on transportation devices, or transportation infrastructure. Whilst the motorist is, in general, interested in speed of his journey, LOS is a more holistic approach, taking into account several other factors. As a result LOS is regarded a measure of traffic density (or a measure of congestion), rather than overall speed, of the journey. It is however closely linked to transportation time (the shorter, the better) [6].

Levels of service range from A to F; A being the best when drivers are not influenced by other vehicles, and F being the worst, forced flow or “jammed.” LOS is measured by speed, volume to capacity (v/c) ratio, and service flow rate. LOS D is generally considered acceptable. Vehicle speeds are relatively unaffected, and it accounts for 80 - 90% of capacity.

Levels of service for intersections are measured in terms of the "average stopped delay" per vehicle over a 15 minute analysis period [7].

Vehicle queuing is an important measure of effectiveness that should be evaluated as part of all analyses of signalized intersections. Estimates of vehicle queues are needed to determine the amount of storage required for turn lanes and to determine whether spillover occurs at upstream facilities (driveways, unsignalized intersections, signalized intersections, etc.). Approaches that experience extensive queues also are likely to experience an overrepresentation of rear-end collisions. Vehicle queues for design purposes are typically estimated based on the 95^{th} percentile queue that is expected during the design period [2].

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].

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 Baghdad .This can be achieved by the estimation of the existing LOS at the study area.
2. Preparation of the best proposed geometric design at study area to achieve a suitable LOS at the present time and during the design period of the project.

3. Study Area

Baghdad, the capital of Iraq, lies on the river Tigers, in the central region of the country. It is the city of the largest population in Iraq, the most important business and commercial center. The rapid increase of Baghdad 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 minimize and eliminate these problems, Maysaloon and AlBayda'a squares are selected. Both locations have congested traffic and represent significant traffic facilities in Baghdad traffic system due to the following reasons:

1. Maysaloon Sq. connects Palestine Street with Albaladiyate and represents one of the main intersections in Rissafa side of Baghdad. While AlBayda'a Sq. connects new Baghdad with Maysaloon sq. and Dorah expressway.
2. There are many attraction locations close to the study area, such as; new Baghdad market, Bayda'a cinema, central garages…etc.

The previous mentioned factors, in addition to other factors, produce the existing high traffic volume and the high congestion due to the limited flow capacity.

The existing geometric design at Maysaloon square, which is represented by the unsignalized intersection, is not sufficient to operate within the required capacity. The same notes can be applied on AlBayda'a sq.

Figure (1) presents the study area and its boundary.

Figure (1) Satellite image of the study area

4. 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.

4-1 Traffic Volumes

The traffic volume account was carried out at Maysaloon and AlBayda'a Square from (7:00 am to 5:00 pm) during the workdays of the week on May 2008 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 wheels includes the PC.
2. Large vehicles: any vehicles move on more than four wheels.

The period of the volume counting is divided into 15 minutes intervals; **Tables (1)**, **(2)** show the total a volume for all approaches each one hour at both squares.

Table (1) Traffic volume at Maysaloon square for all approaches each one hour

Time	From Palestine St.			From Mohammed Alqasem St.			From Al-Baladiyate		
	R	TH	L	R	TH	L	R	TH	L
7:00-8:00 a.m	208	627	175	115	356	775	207	442	286
8:00-9:00	215	689	237	177	481	899	330	505	409
9:00-10:00	227	683	231	151	458	818	249	464	328
10:00-11:00	205	660	208	108	422	770	201	440	278
11:00-12:00	223	676	224	124	393	770	201	449	280
12:00-1:00	244	698	246	146	409	811	243	472	321
1:00-2:00	273	729	277	177	489	875	306	504	386
2:00-3:00	293	755	304	204	574	929	361	536	440
3:00-4:00	260	681	229	150	531	881	313	468	280
4:00-5:00 p.m	128	463	39	30	372	640	141	368	110

TH: Through movement.
R: Right movement.
L: Left movement.

Table (2) Traffic volume at AlBayda'a square
For all approaches each one hour

Time	From Dorah expressway			From new Baghdad			From Maysaloon Sq.			From AlNeariya		
	R	TH	L	R	TH	L	R	TH	L	R	TH	L
7:00-8:00 a.m	90	429	125	69	132	11	537	75	152	69	34	69
8:00-9:00	123	574	342	270	429	40	707	99	202	104	52	104
9:00-10:00	122	570	345	275	263	25	637	90	181	93	45	93
10:00-11:00	113	534	383	328	418	39	703	99	201	98	48	98
11:00-12:00	121	577	385	333	423	41	705	100	200	103	51	103
12:00-1:00	129	612	399	352	480	46	730	103	208	110	54	110
1:00-2:00	133	633	444	377	654	65	805	113	229	122	60	122
2:00-3:00	138	629	489	377	690	83	883	125	252	137	67	137
3:00-4:00	123	567	351	284	359	35	676	94	192	99	49	99
4:00-5:00 p.m	98	450	89	52	63	6	554	78	158	71	34	71

4-2 Saturation Flow Rate

In order to calculate the saturation flow rate, which represents the main parameter that has a major effect in the capacity of intersection, a Highway Capacity Software (HCS) is used. **Tables (3)** and **(4)** show the calculated saturation flow at stop line for all approaches at both Maysaloon and AlBayda'a Sq's.

Table (3) Calculated saturation flow rate at Maysaloon square

Approach	Movement	Saturation Flow Rate (vphg)
From Palestine St.	TH	4532
	L	4306
From Mohammed Alqasem St.	TH	5586
	L	4264
From Al-Baladiyat	TH	5586
	L	4264

Table (4) Calculated saturation flow rate at AlBayda'a square

Approach	Movement	Saturation Flow Rate (vphg)
From Dorah expressway	TH	4189
	L	2828
From new Baghdad	TH	4446
	L	3001
From Maysaloon Sq.	TH	2916
	L	3030
From AlNeariya	TH	1676
	L	1593

4-3 Existing Geometric Design

To evaluate the level of service (LOS) at both Maysaloon and AlBayda'a Sq's., 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 squares.

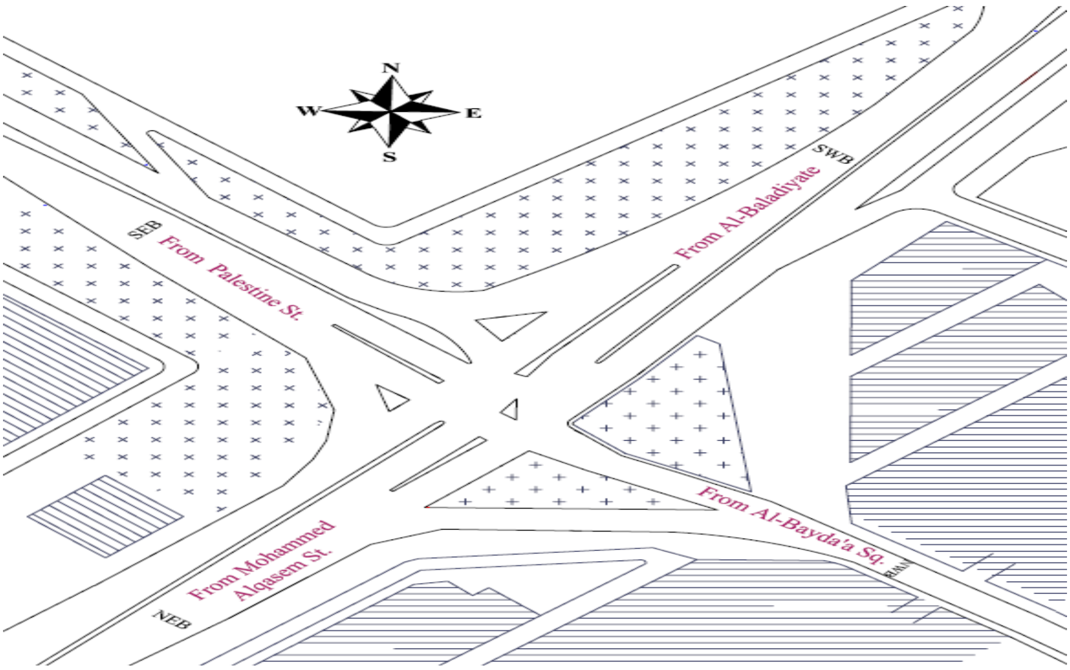

Figure (2) Existing geometric layout for Maysaloon square

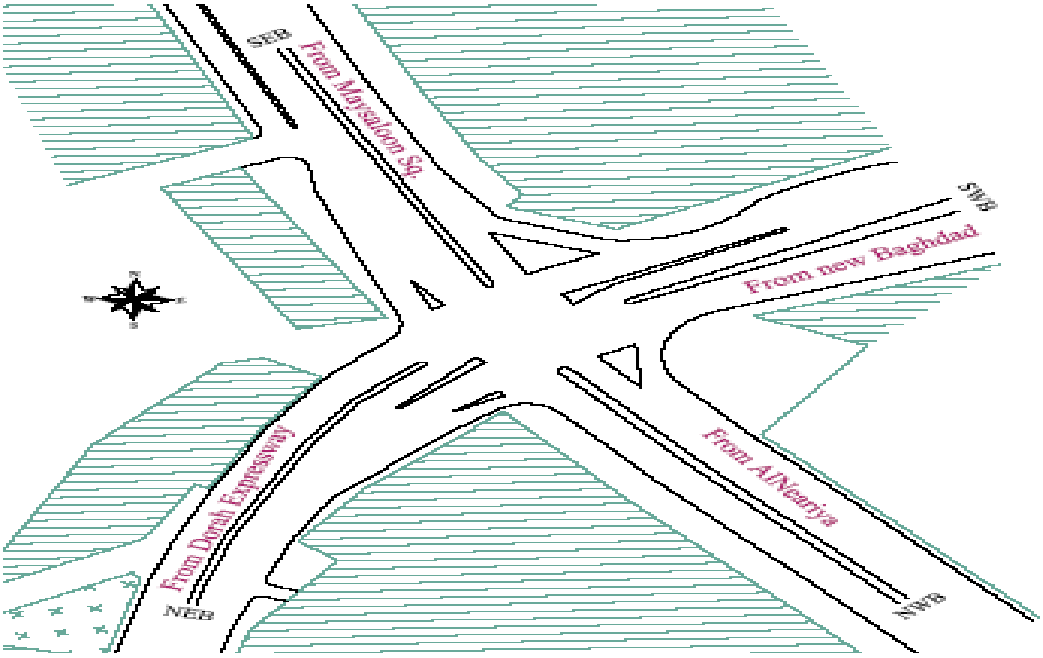

Figure (3) Existing geometric layout for AlBayda'a square

5. Analysis and Results

5-1 Peak Hour Volumes

An excel program is used to analyze the traffic account shown in **Table (1)**, **(2)** to specify the peak hour. From site investigation and traffic account, the following conclusions were observed:

a) The peak hour at both Maysaloon and AlBayda'a Sq's. are found to be between 2:00-3:00 p.m. The total traffic volumes during this hour at both Maysaloon and AlBayda'a Sq's were 4396 and 4007 pc/h respectively. **Figures (4)** and **(5)** show the peak hour during the time period of survey at each square.

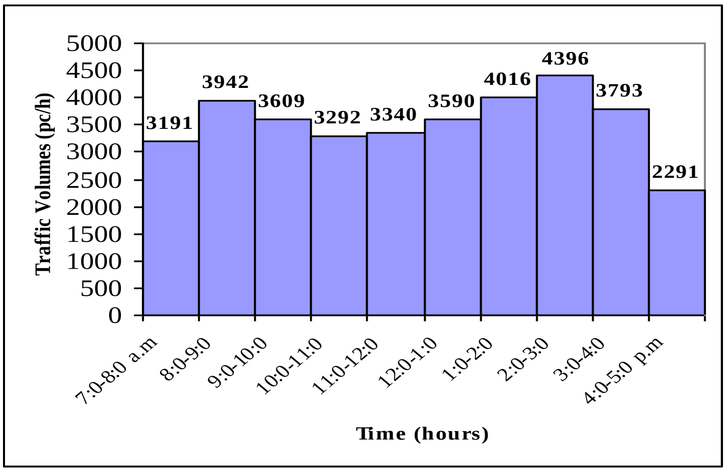

Figure (4) Total traffic volumes at Maysaloon square each one hour

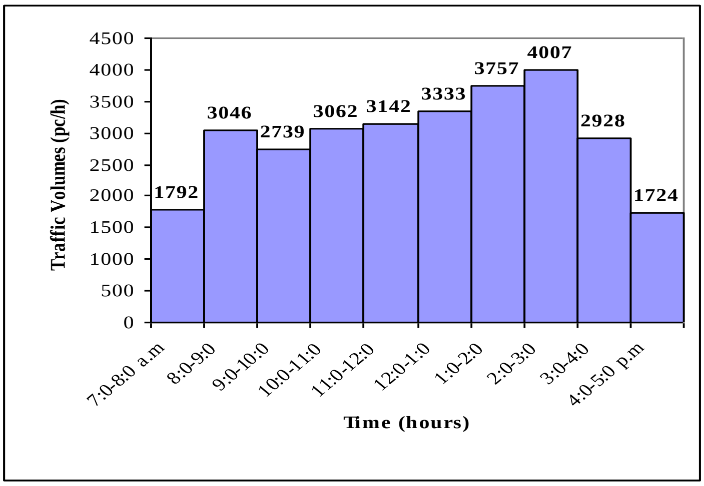

Figure (5) Total traffic volumes at AlBayda'a square each one hour

b) The percentage of heavy vehicles at Maysaloon square was concentrated on the approaches that come from Mohammed Alqasem St. and Al-Baladiyat, as shown in **Table (5)**, while the percentage of heavy vehicles at AlBayda'a square was concentrated on the approach that comes from new Baghdad as depicted in **Table (6)**.

Table (5) Percentage of heavy vehicles for all approaches at Maysaloon square

Approach	Percent of Heavy Vehicles
From Palestine St.	3.0
From Mohammed Alqasem St.	4.0
From Al-Baladiyat	4.0

Table (6) Percentage of heavy vehicles for all approaches at AlBayda'a square

Approach	Percent of Heavy Vehicles
From Dorah expressway	4.0
From new Baghdad	5.0
From Maysaloon Sq.	4.0
From AlNeariya	2.0

5-2 Peak Hour Factor (PHF)

The PHF is defined as the ratio of total volume to the maximum 15 min rate of flow within the hour. **Tables (7)** and **(8)** depict PHF values for all approaches at both squares.

Table (7) PHF Values for Maysaloon square approaches

Approach	Movement	PHF
From Palestine St.	R	0.99
	TH	0.99
	L	0.97
From Mohammed Alqasem St.	R	0.96
	TH	0.99
	L	0.98
From Al-Baladiyat	R	0.96
	TH	0.99
	L	0.97

Table (8) PHF Values for AlBayda'a square approaches

Approach	Movement	PHF
From Dorah expressway	R	0.99
	TH	0.99
	L	0.99
From new Baghdad	R	0.99
	TH	0.97
	L	0.99
From Maysaloon Sq.	R	0.99
	TH	0.98
	L	0.98
From AlNeariya	R	0.98
	TH	0.99
	L	0.98

5-3 Existing LOS

5-3-1 at Maysaloon Square

To evaluate the existing LOS Highway Capacity Software (HCS) program is adopted. It was found that the LOS at the base year is LOS (D) as shown in **Table (9)**.

Table (9) Existing LOS at Maysaloon square

Approach	Average Delay sec/veh	LOS
From Palestine St.	24.3	C
From Mohammed Alqasem St.	76.2	E
From Al-Baladiyat	22.7	C
Average intersection delay	45.9	D

5-3-2 at AlBayda'a Square

By using the same software package, it was found that the LOS at the base year is LOS (E) as shown in **Table (10)**.

Table (10) Existing LOS at AlBayda'a square

Approach	Average Delay sec/veh	LOS
From Dorah expressway	117.4	F
From new Baghdad	58.7	E
From Maysaloon Sq.	28.7	C
From AlNeariya	27.7	C
Average intersection delay	77.9	E

6. Proposal Design Alternative

6-1 at Maysaloon Square

Four geometric design proposals were suggested: the first proposal is to make the intersection operate with four legs instead of three. It is found from the results shown in **Table (11)** that the addition of a fourth leg that's proposed to come from AlBayda'a square made the intersection operate on (LOS F). Therefore, this proposal is not recommended to improve the operation and it is necessary to adopt another proposal.

Table (11) LOS at Maysaloon square within the first proposal

Approach	Average Delay sec/veh	LOS
From Palestine St.	38.8	D
From Mohammed Alqasem St.	171.9	F
From Al-Baladiyat	35.9	D
From AlBayda'a square	211.4	F
Average intersection delay	118.7	F

The second proposal is to execute a flyover that connects Mohammed Alqasem St. with Al-Baladiyat by considering the existence a fourth leg which comes from AlBayda'a square. It is clear from the results that were shown in **Table (12)**; the LOS was (LOS E). So the execution of this proposal will not make any improvement on the traffic performance operation, therefore; another proposal was adopted.

Table (12) LOS at Maysaloon square within the second proposal

Approach	Average Delay sec/veh	LOS
From Palestine St.	62.6	E
From Mohammed Alqasem St.	80.5	F
From Al-Baladiyat	55.9	E
From AlBayda'a square	85.4	F
Average intersection delay	72.6	E

The third proposal is to execute a flyover that connects Mohammed Alqasem St. and Al-Baladiyat while the square is kept operating with three legs. It is clear from the results that were shown in **Table (13)** that the LOS was (LOSD). Also the execution of this proposal will not make any improvement on the LOS, therefore; the fourth proposal was adopted.

Table (13) LOS at Maysaloon square within the third proposal

Approach	Average Delay sec/veh	LOS
From Palestine St.	28.0	C
From Mohammed Alqasem St.	68.9	E
From Al-Baladiyat	28.6	C
Average intersection delay	43.7	D

The fourth proposal is to execute an overpass from Palestine St. towards Al-Dorah expressway at a AlBayda'a square. Inspite the fact that the LOS will remain constant (LOS D) as shown in **Table (14)**, but it is considered good particularly when a four leg which was coming from AlBayda'a square, was added. **Figure (6)** shows the distribution of traffic volumes at the existence of an overpass.

Table (14) LOS at Maysaloon square within the fourth proposal

Approach	Average Delay sec/veh	LOS
From Palestine St.	39.1	D
From Mohammed Alqasem St.	58.8	E
From Al-Baladiyat	45.1	D
From AlBayda'a square	29.9	C
Average intersection delay	49.1	D

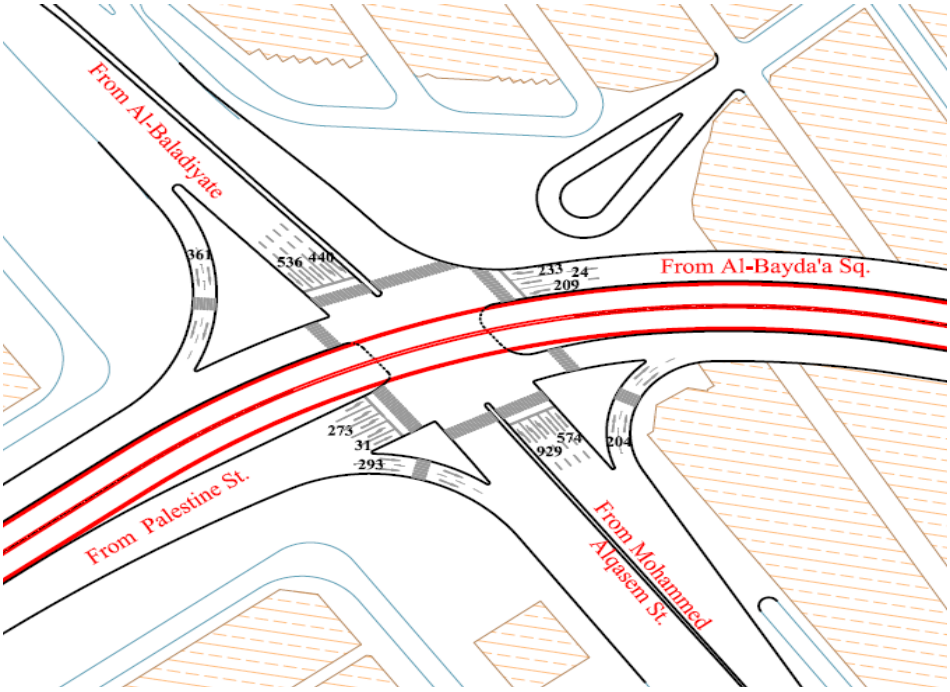

Figure (6) Distribution of traffic volumes at Maysaloon Sq. within the existence of an overpass

6-2 at AlBayda'a Square

Two geometric design proposals were also suggested: the first proposal is to execute a flyover that connects Al-Dorah expressway with new Baghdad. It is clear from the results that were shown in **Table (15)**, the LOS was (LOS E). So this proposal didn't improve the traffic performance operation, therefore; it is important to adopt another proposal.

Table (15) Existing LOS at AlBayda'a square within the first proposal

Approach	Average Delay sec/veh	LOS
From Dorah expressway	133.4	F
From new Baghdad	38.5	D
From Maysaloon Sq.	35.1	D
From AlNeariya	35.5	D
Average intersection delay	76.8	E

The second proposal is to execute an overpass that connects Al-Dorah expressway at AlBayda'a square with Maysaloon square. It was found that the execution of this proposal can improve the LOS to LOS C as shown in **Table (16)**. **Figure (7)** demonstrates the traffic volumes with all movements at the existence of overpass.

Table (16) Existing LOS at AlBayda'a square within the second proposal

Approach	Average Delay sec/veh	LOS
From Dorah expressway	33.4	C
From new Baghdad	30.4	C
From Maysaloon Sq.	45.4	D
From AlNeariya	35.4	D
Average intersection delay	34.7	C

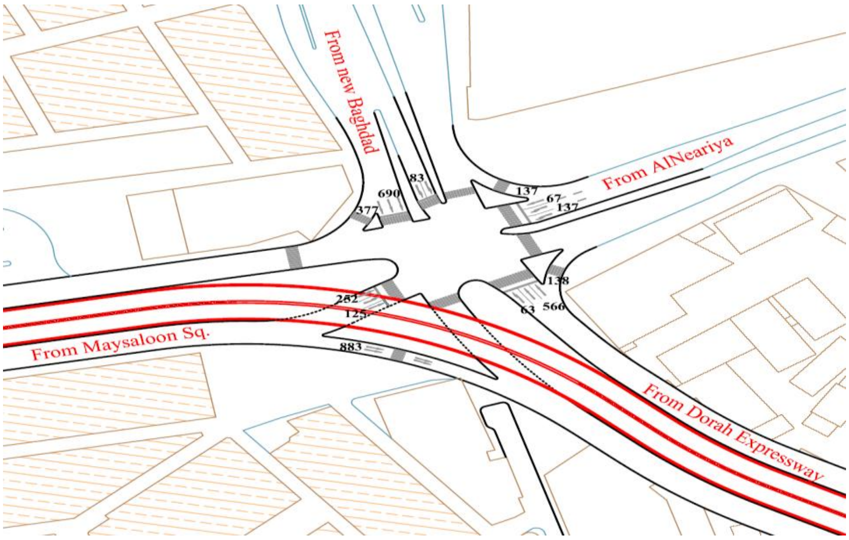

Figure (7) Distribution of traffic volumes for the second proposal at AlBayda'a square at the existence of an overpass

7. Analysis of Forecasted Traffic Data

HCS program is used to analyze the forecasted data (after 20 years with 2% annual growth rate) through calculation of capacity, delay and LOS for all approaches and the whole intersection. For target year.

7-1 at Maysaloon square

From the obtained data it was found that the LOS at the target year will be LOS (E) as shown in **Table (17)**.

7-2 at AlBayda'a square

It was found from the obtained data, that the LOS at the target year will be LOS (E) as shown in **Table (18)**.

Table (17) LOS at Maysaloon square at the target year

Approach	Average Delay sec/veh	LOS
From Palestine St.	45.4	D
From Mohammed Alqasem St.	109.6	F
From Al-Baladiyat	49.0	D
From AlBayda'a square	52.1	D
Average intersection delay	77.7	E

Table (18) LOS at AlBayda'a square at the target year

Approach	Average Delay sec/veh	LOS
From Dorah expressway	105.4	F
From new Baghdad	59.9	E
From Maysaloon Sq.	49.7	D
From AlNeariya	37.1	D
Average intersection delay	69.9	E

8. Discussion of the Results

From the results of the traffic analysis of Maysaloon and AlBayda'a squares performance by the aid of HCS program, it is noticed that the problem is concentrated in the approach that was coming from Palestine St. in Maysaloon Sq. and in the approach that was coming from Dorah expressway in AlBayda'a Sq.

To improve the traffic performance operation of these squares, it is important to adopt several alternatives to reduce the stopped delay time and improve the level of service.

9. Conclusions

1. Using HCS computer package facilitates the analysis and evaluation of the existing and future traffic condition, therefore; it minimize time consumption, effort, and ensure more accurate results as compared manually.
2. The existing condition of Maysaloon and AlBayda'a squares need improvements to reduce their delay time and raise their level of service (LOS).

10. Recommendations

From the conclusions of this research, the performance of these intersections requires to adopt several alternatives in order to increase the LOS and reduce the stopped delay time. It is found that the best suitable one which is recommended to be executed is to construct a flyover that connects Maysaloon square with AlBayda'a square towards Dorah expressway by consider the proposed geometrical design and the required number of lanes as presented in proposals four and two for Maysaloon and AlBayda'a Sq.'s respectively.

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