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Performance of a local signalized intersection for handling traffic operation in Baghdad City

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ABSTRACT

The inspection of the flexibility and performance of a local signalized intersection in managing traffic operation in Baghdad city is the main target of this study. Andalus intersection is one of the important local intersections in Bagdad city which recorded remarkable traffic congestion problem now a days and have been chosen in this study as a part of continuous studies due to its vital location. Smart Traffic Analysis (STA) software is used to give an aspect to the inefficient performance of the Andalus signalized intersection having three approached links and four exit legs while SYNCHRO software is used to simulate the data analysis and offer different alternative solutions to solve the congestion problem. From the obtained data analysis it has been found that the best suggested alteration for handling the current traffic volume of each studied intersection approach is the signalized intersection with optimum cycle time combined with the addition of two lanes, where the mean delay for the entire intersection can be reduced by approximately 26% by applying alteration No.1 while the mean delay for the entire intersection can be reduce approximately by 31% by applying alteration No.2. Furthermore, the queue length for the entire intersection can be reducing by approximately 6% and 17% for alteration No.1 and No.2 respectively.

Keywords: SYNCHRO, Intersection, LOS, Delay, STA

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1. Introduction

Intersections have a great influence on the road network, where the traffic flows can be released in different directions. The intersection's capacity is considered to be lower than their approach links. Due to the bottleneck cases that mostly founded at the intersections of the road network, the intersections become the familiar source of the traffic accidents and traffic jam. Thus, it is important to study the traffic flow characteristics at the signalized intersections, as the capacity of the intersection can be improved according to their properties. Studying the traffic flow characteristics at signalized intersections is one of the most effective and immediate measurements to enhance the performance of road networks and decrease the congestion in cities. Generally, the lost time is occur each time a movement is begin and stop due to the timing of the control signal, and the quantity of lost time can affect the delay and capacity so it is significant to estimate the lost time value accurately.

1.1 Study objectives

The objectives of this study can be summarized as follows:

1. To evaluate the traffic performance of the selected signalized intersection by using STA and SYNCHRO software.
2. To suggest different alternatives solutions to release the traffic congestion of the selected signalized intersection using SYNCHRO software.
3. To compare between the proposed solutions and select the most reasonable one to improve the performance of the selected signalized intersection.

2. Literature review

The Highway Capacity Manual (HCM) defined the delay as the primary tool that measures the effectiveness of the roundabout and intersections, with Level of Service (LOS) that determined and organized from the delay measurements [1]. To quantify the level of service at the intersections, the Highway Capacity Manual uses the total delay, as a sum of the control delay and geometric delay, as well as the queue length. It is defined as an index that refers to the appropriate design of the geometric characteristics for an intersection approach. Average queue length could be assumed as an equivalent to the approach delay/hr or vehicle/hr. It has great benefit as an evaluation tool for intersections performance with other intersection types [2].

Many of studies were done to monitor and enhance the traffic operation, and settle the congestion at the signalized intersections using HCM method [3] and [4]. The HCM in their studies played an important role to analysis traffic capacity and LOS for the chosen signalized intersections and assist in give better proposed solutions.

Nikiforos S. and Adam K. used the Intersection Design Alternative Tool (IDAT) to improve the intersection design practices. The improvement achieved by creating additional design alternatives and comparing among them. The tools assist for providing an evaluation for the intersection operations and safety considerations through the development of the software [5].

Al-Kubaisy used SIDRA computer program for the studying and analyzing the traffic operation in the Kahtan roundabout which is located in Baghdad the capital of Iraq. Two proposed alternatives were adopted to enhance the traffic condition in this area. The first alternative involves to replacing the current roundabout by a 4-leg signalized intersection providing the possible additional lanes in each high volume direction and using the most available unused area and the second one involves to placing a flyover at the main traffic movement path (starting from Al-Yarmok general hospital-passing through Kahtan roundabout toward Al-Baya'a district). The data analysis found that a flyover at the main traffic movement path at Kahtan roundabout is the best alternative to enhance the traffic operation and capacity at Kahtan roundabout [6].

This study focus on the performance of the one of the signalized intersection in Baghdad city which is the Andalus square using an intelligent technique known as SYNCHRO computer software for handling the restricted traffic operation.

3. Methodology and data collection

There is a high number of signalized intersections in Baghdad city. This signalized intersection can be diverged in shape, having multiple legs and dimensions, and sufficient in clearance which can be suitable for the requirement of the survey as well as traffic volume characteristics. The above-mentioned elements highly influence the selection of the signalized intersection in this study in addition to the availability of the necessary traffic data for the simulation of the selected computer program. As a result, the location of the Andalus signalized intersection found to be meeting the desired criteria in term of operating condition. After the collection of the necessary traffic volumes and geometric data, the geometric design has been obtained in details to fulfill the requirement of the simulation progress of the SYNCHRO computer software.

3.1 Andalus signalized intersection

Andalus signalized intersection considered to be one of the most important junctions in Baghdad city due to its vital location at the center. It includes various important buildings such as government buildings, hospitals, shops; and restaurant and many of public and private parkings as well as being a short way to the Central Business District (CBD) of Baghdad city. The three approaches of signalized intersection labeled as: Westbound (WB), Northbound (NB), and Eastbound (EB). The intersection is located in the Rusafa district and having four exits that release the traffic coming from the three entrances as shown in Fig. 1.

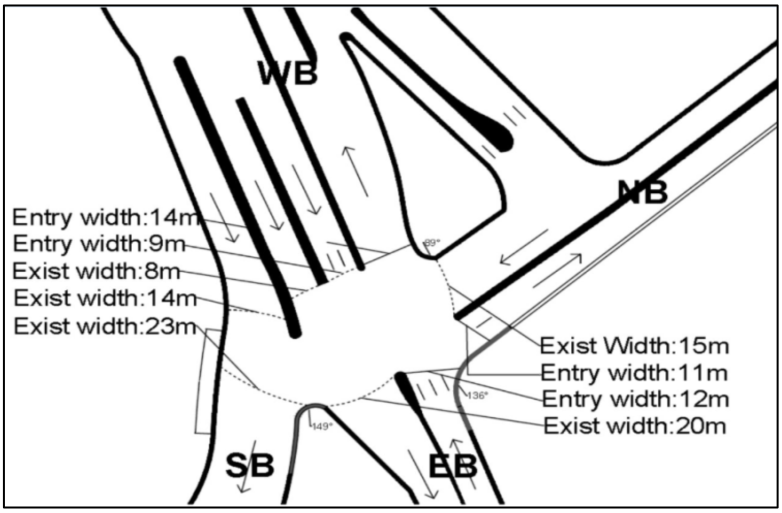

Figure 1. Andalus intersection layout

3.2 Simulation package

3.2.1 Smart traffic analyzer (STA)

STA is a professional system that used as a mean of traffic management. This intelligent transportation system recording the required collected data concerning volumes, speed, classification of vehicles, incident, unusual stopped vehicles and illegal detected movement in addition to any other recorded facilities [7]. STA was chosen in this study and the traffic monitoring cameras were used for this purpose as shown in Fig. 2.

Figure 2. Smart traffic analyzer (STA) data presentation

3.2.2 SYNCHRO Software

SYNCHRO is the most popular macroscopic traffic signal timing tool analysis and one of the optimization software applications [8] and [9]. This program of simulation is backing the Highway Capacity Manual's (HCM) 6th Edition methodology for the signalized and unsignalized intersections, and for roundabouts. It was recorded that the HCM procedures for calculating delays and LOS are embedded in SYNCHRO; thus, the user does not need to acquire HCM software [8]. SYNCHRO has no limitations on the number of links and nodes. It also implements the Intersection Capacity Utilization method for determining intersection capacity. This program provides traffic engineers more options while developing the signal timing plans and thus, allows the user to weight specific phases by the signal optimization routine. Because of its simplicity in usage and rapidity in modeling which can be accomplished by traffic engineers within days, SYNCHRO program remains the leader among the traffic analysis applications [9], and for the mentioned raisons this program was chosen in this study. The laying out and simulation information of the Andalus intersection is shown in Fig. 3.

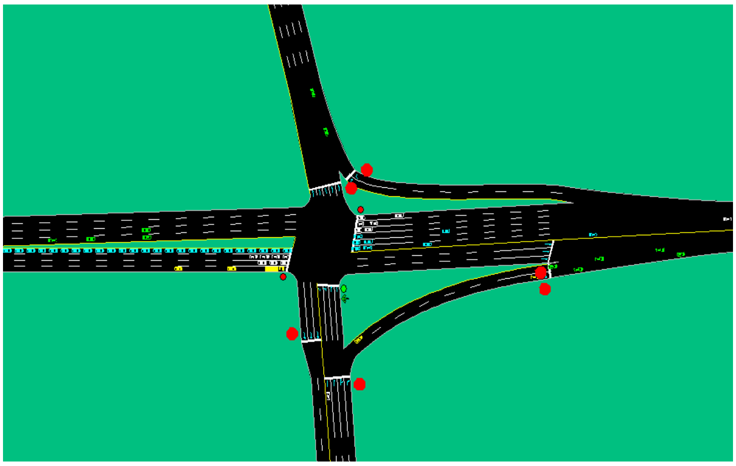

Figure 3. Andalus simulation using SYNCHRO software

3.3 Data collection

The traffic data for the Andalus square collected by means of high speed and resolution cameras located in a manner to allow capturing all the necessary details.

STA software was used in this study to explore the actual condition of the selected signalized intersection which is given the code of (Current Situation). After displaying the recorded videos, the required output results for the Andalus signalized intersection including the traffic volume, headway, delay and other important parameters were presented. The data was collected at two important time intervals: morning (from 7:00 to 9:00 am) and afternoon (from 14:00 to 16:00 pm) which are defined as the peak hours for this intersection. According to the Level of Service (LOS) criteria of the HCM, LOS for each approach is also determined [1]. Table 1 explores the LOS criteria for the signalized intersection.

Table 1. Level of Service (LOS) criteria for signalized intersection [1]

LOS	Average Control Delay (sec/veh)	General Description
A	≤10	Free flow
B	>10-20	Stable flow (slight delays)
C	>20-35	Stable flow (acceptable delays)
D	>35-55	Approaching unstable flow (tolerable delay, occasionally wait through more than one signal cycle before proceeding)
E	>55-80	Unstable flow (intolerable delay)
F	>80	Forced flow (congested and queue fail to clear)

In addition to the above mentioned techniques, general survey to the study area has been done during the investigated stage to record any constraints or illegal behaviors from the road users which can affect the performance of the Andalus intersection.

In order to tackle and medicate the situation of the current performance of the Andalus intersection, two alternatives were suggested, analyzed and discussed using SYNCHRO simulation software.

4. Data analysis and discussion

4.1 Current situation

The different approaches behavior for the Andalus signalized intersection is illustrated in Fig. 4 to 6 which showed the average delay of the vehicles traveling from each of the (WB), (NB), and (EB) respectively towards the other approaches. It can be clearly noticed that the average delay grows due to the increment in vehicle travel distance in this intersection and excluding by the right turn, LOS for the 1st, 2nd, 3rd, and 4th hours are found to be (F) for the WB and NB approaches while the LOS of EB was found to be vary between (E and F). The right turn recorded better LOS in all the intersection approaches as it is always free from any amputation as shown in Table A in the Appendix. The main reason for reaching LOS F is the excessive number of vehicles that couldn't accommodated sufficiently by the intersection and the insufficient number of lanes in the exit leg of the NB.

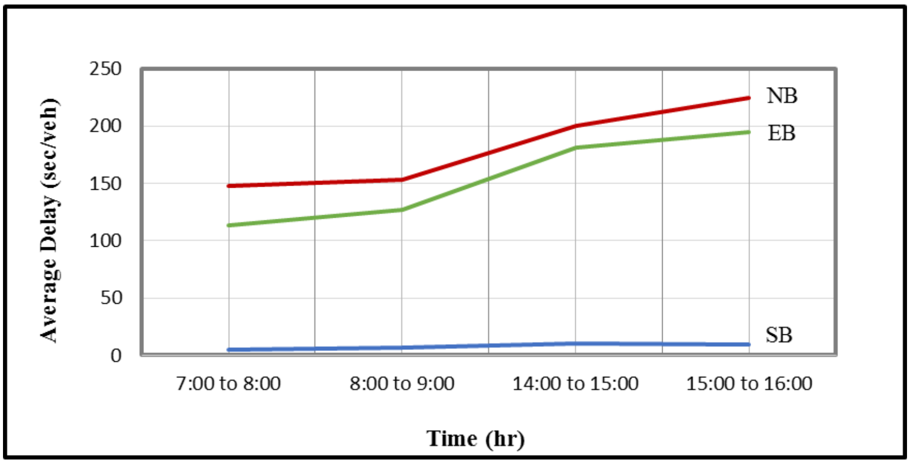

Figure 4. The average delay outputs of the Current Situation for the Andalus signalized intersection for vehicle traveling from WB to all approaches

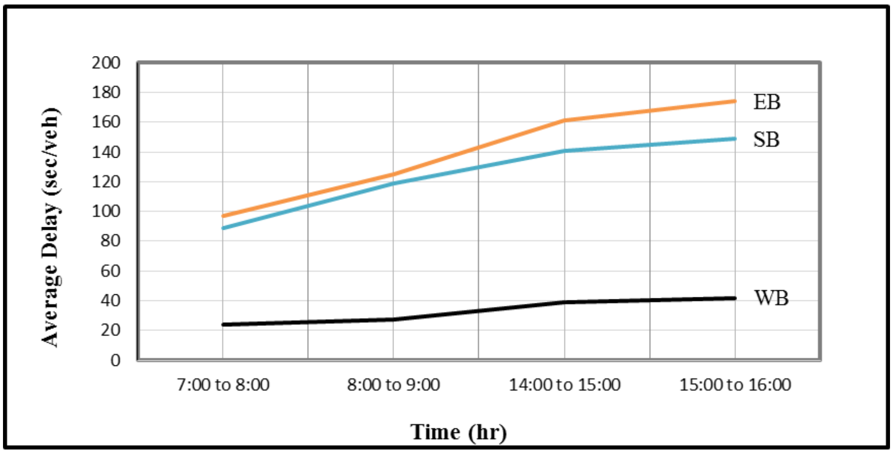

Figure 5. The average delay outputs of the current situation for the Andalus signalized intersection for vehicle traveling from NB to all approaches

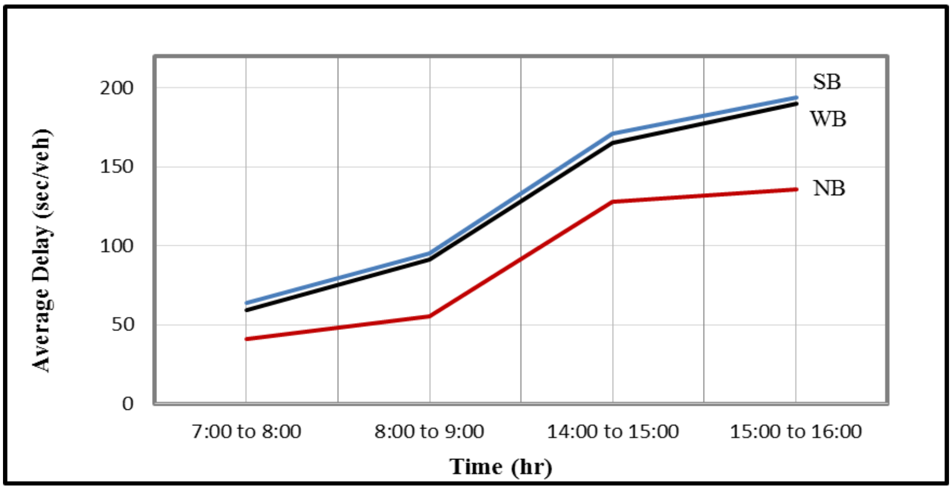

Figure 6. The average delay outputs of the current situation for the Andalus signalized intersection for vehicle traveling from EB to all approaches

The queue length for each approach was used also to give an indication to the performance of the intersection as presented in Table 2 which showed clearly that at the selected time of study, there was a long queue recorded in all of the different legs of the intersection due to the insufficient number of lanes which is two lanes only specially concerning the exit leg of the NB, and there was a variation in the queue length among these legs which is mainly contributed to the reason of: in the mourning peak period, the Andalus intersection is an attractive area and the significant number of traffic volume (approximately 42% of the vehicles) is

constrained in NB entrance as the majority of this traffic volume is coming from the east of Baghdad which is an area that has a high number of population who using this approach to go to their destination in CBD, and half of these vehicles traveled in straight line towards SB, while only (6%) traveled left causing remarkable reduction in the queue length in all other approaches. On the contrary, at the evening peak period the traffic volume is highly grown in both WB and EB while decreased from the entrance of NB. In another hand the exit of NB is much restricted due to the insufficient number and width of lanes causing a remarkable increment in the left turn movement and thus creates a bottleneck and consequently led to an increment in the average queue length in all other approaches.
Other important defect which captured by the cameras and recorded during the survey and can be contributed somehow to the congestion of this intersection is the traffic violations and illegals behaviors either from the drivers, pedestrians or even from other road users which affected the performance of the Andalus signalized intersection.

Table 2. The current situation of the queue length output for the Andalus signalized intersection

Approach Name	Mean Queue (m)			
	(7:00-8:00) am	(8:00-9:00) am	(14:00-15:00) pm	(15:00-16:00) pm
NB	61	87.5	150	167
EB	103.5	111	138.5	147
WB Right	97.5	115	206.5	225.5
WB Left	118.5	131	222	249.5

4.2 Alteration No.1

The first proposed alternative for handling traffic operation in the Andalus intersection is by trying different cycle time using SYNCHRO simulation software and given the code of (Alteration No.1). By using this technique it was observed that the average delay for both morning and evening peak hours were improved by around 15%, 18%, and 12% for each WB, EB, and NB respectively comparing with the current situation. The LOS is found to be enhanced specially at the 1st and 2nd morning peak hours as shown in Table B in the Appendix, for example the average delay for vehicle travelling from WB to EB was 70 and 80 veh/hr which gives the LOS (E) instate of LOS (F) which is recorded previously for the current situation according to the Table 1.
The recorded observation was that: by trying a series of simulation using SYNCHRO software, the optimum cycle time (OCT) was adopted and by detracting the illegal traffic movement as well, the delay can be reduced and as a sequence, the LOS can be enhanced to achieve better performance for the Andalus intersection. The average delay outputs of alteration No.1 for vehicle traveling from WB, NB, and EB to the other approaches of the Andalus intersection with optimum cycle time using SYNCHRO simulation software is presented in Fig. 7 to 9.

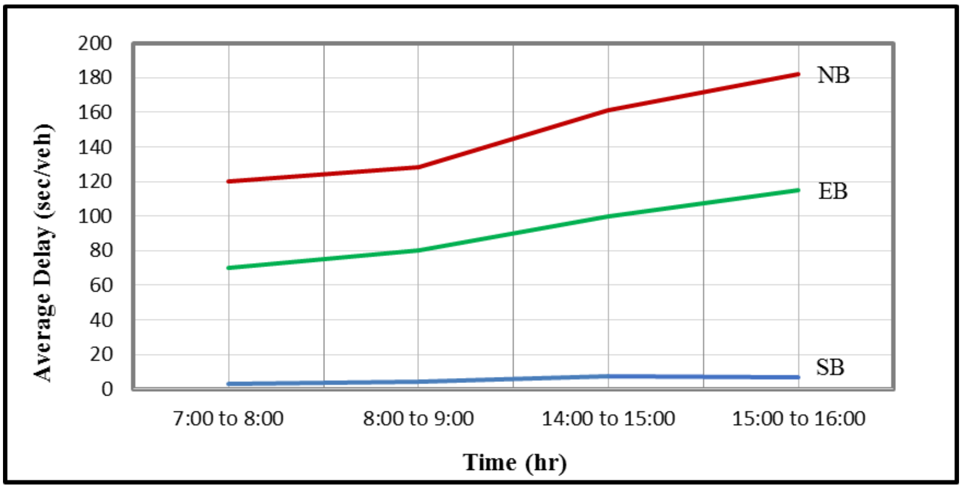

Figure 7. The average delay outputs of alteration No.1 for Andalus signalized intersection for vehicle traveling from WB to all Approaches

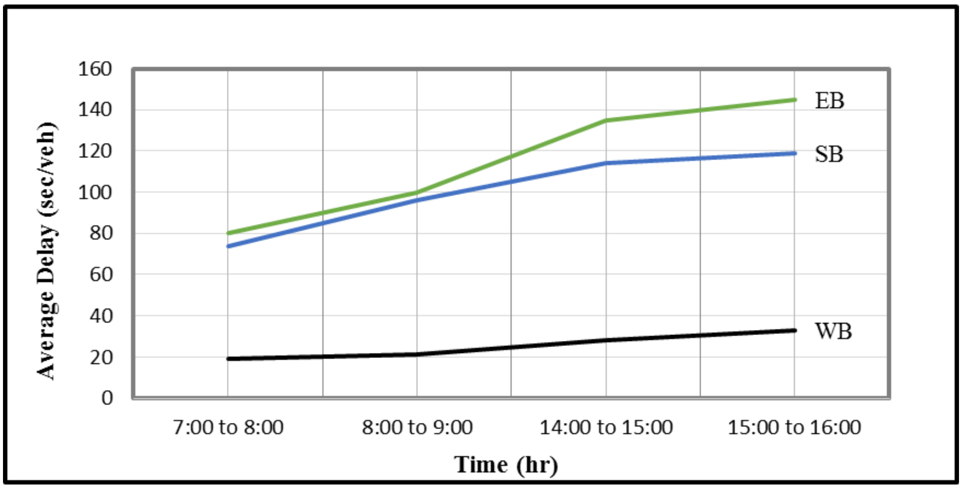

Figure 8. The average delay outputs of alteration No.1 for Andalus intersection for vehicle traveling from NB to all approaches

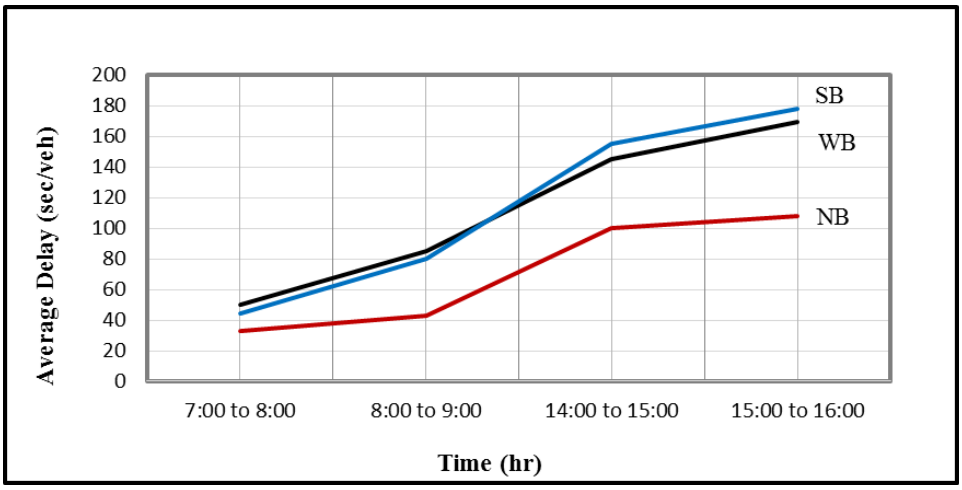

Figure 9. The average delay outputs of alteration No.1 for Andalus intersection for vehicle traveling from EB to all approaches

Using the optimum cycle time (OCT) by means of SYNCHRO software, the queue length is almost decreased by around 17%, 20%, and 14% for each WB, EB, and NB respectively which are less comparing to the current situation because of using different cycle time that achieved better performance specially for the morning peak hours. Table 3 presented the queue length for each approaches of the Andalus signalized intersection after trying alteration No.1.

Table 3. The queue length output of the alteration No.1 for the Andalus signalized intersection

Approach Name	Mean Queue (m)			
	(7:00-8:00) am	(8:00-9:00) am	(14:00-15:00) pm	(15:00-16:00) pm
NB	50.12	56.23	139.28	150.70
EB	86.29	100.49	121.54	138.69
WB right	44.91	120.89	185.64	201.32
WB left	63.01	138.72	199.37	199.03

4.3 Alteration No.2

The second proposed alternative for handling traffic operation in the Andalus signalized intersection is by adding two lanes to the NB exit leg by means of SYNCHRO simulation software and given the code of (Alteration No.2) as shown in Fig. 10.

Figure 10. Andalus simulation using SYNCHRO software (Alteration No.2)

By using this alternative solution, it was found that the average delay decreased by around 25%, 22%, and 15% for the WB, EB, and NB respectively as compared with the current situation. This improvement was led to enhance the LOS especially at the morning peak hour to reach (E) for the traffic coming from WB to NB and EB and the same LOS was recorded for the traffic coming from NB to EB and SB. Concerning the EB approach the LOS was obviously found to be increased for traffic coming from EB to SB and WB to become (C and D) respectively as shown in Table C in the Appendix. Fig. 11 to 13 presents the results of the Andalus signalized intersection wile added two lanes to the NB exit leg using SYNCHRO simulation software.

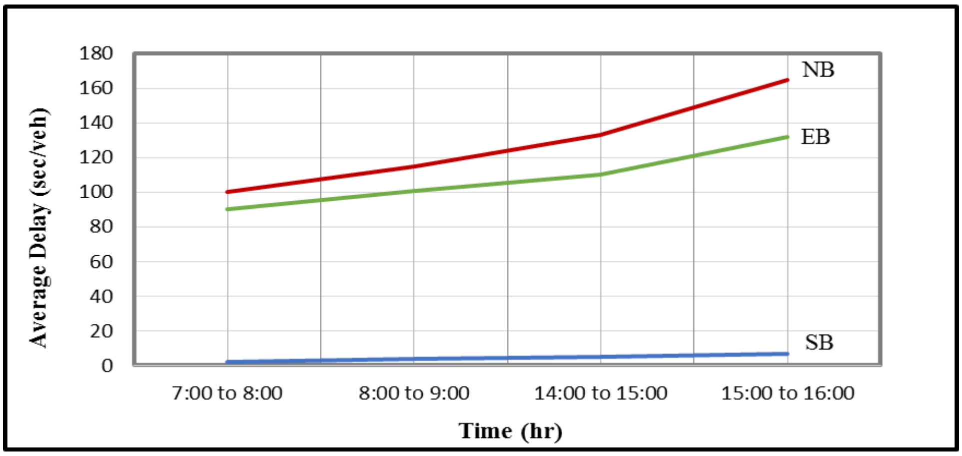

Figure 11. The average delay outputs of alteration No.2 for Andalus signalized intersection for vehicle traveling from WB to all Approaches

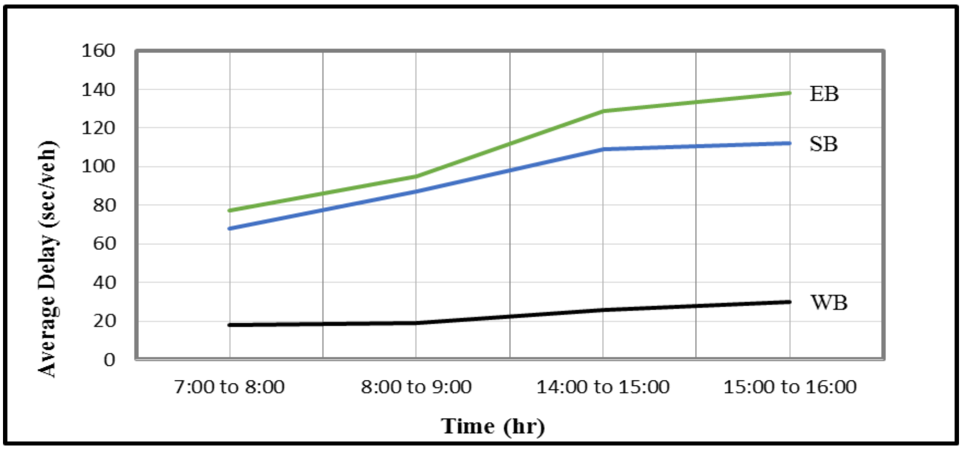

Figure 12. The average delay outputs of alteration No.2 for Andolus signalized intersection for vehicle traveling from NB to all approaches

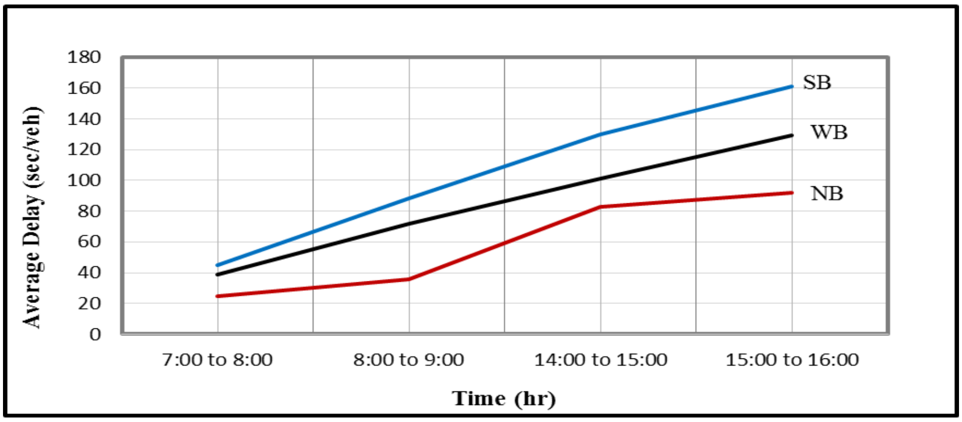

Figure 13. The average delay outputs of alteration No.2 for Andalus signalized intersection for vehicle traveling from EB to all approaches

The queue length output after trying the alteration No.2 of the Andalus signalized intersection showed a clear decrement in the queue length in all of the legs as a result to the addition of the two lanes to the exit leg of the NB as presented in Table 4. It was also observed that at the peak hours the reduction in queue length was almost 27%, 24%, and 17% for the WB, EB, and NB respectively comparing with the current situation.

Table 4. The queue length output of the alteration No.2 for the Andalus signalized intersection

Approach Name	Mean Queue (m)			
	(7:00-8:00) am	(8:00-9:00) am	(14:00-15:00) pm	(15:00-16:00) pm
NB	44.19	49.81	125.39	124.82
EB	69.01	90.33	110.42	110.39
WB right	39.74	103.23	169.02	150.12
WB left	55.55	125.29	175.01	167.70

In general, no noticeable difference in the LOS was founded for the evening peak hour for the majority of approaches of the intersection as its still maintain LOS (F) in spite of the application of the two alterations. These two suggested solutions are mainly proposed for short term application which can be applied as soon as possible to give fast solutions with lowest cost. More effective solutions can be adopted if there is enough budget such as constructing a flyover intersection or grade separated interchanges.

5. Conclusion and recommendation

It has been found out that:

- By only optimizing the cycle time for the Andalus signalized intersection and removing the illegal movement and stops, the mean delay for the entire intersection can be reduced by 26%.
- By optimizing the cycle time for the Andalus signalized intersection and removing the illegal movement and stops combined with the addition of two lanes to the exit leg of NB, the mean delay for the entire intersection can be reduced by 31%.
- By only optimizing the cycle time for the Andalus signalized intersection and removing the illegal movement and stops, the queue length for the entire intersection can be reduced by 6%.
- By optimizing the cycle time for the Andalus signalized intersection and removing the illegal movement and stops combined with the addition of two lanes to the exit leg of NB, the queue length for entire intersection can be reduced by 17%.
- The best suggested alteration for the studied intersection was found to be (signalized intersection with optimum cycle time combined with the addition of two lane) that can handle the current traffic volumes for all approaches of the studied intersection.
- The existence of the separated right lane in the NB and WB is highly recommended for the significant reduction of the mean delay and queue length for the entire intersection.
- The special geometric design configuration for the signalized intersection (three enter legs and four exist legs) found to be helpful in discharging the traffic in better way than the three exit legs only.
- The best location for the design over pass or under pass is recommended to connect NB to SB so that the mean delay can be reduced by 39% and the queue length can be reduced by 21% combined with

optimizing the cycle time and adding two lanes in addition to the removing of the illegal movement and stops.

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Appendix

Table A. Level of Service (LOS) for each approach (Current Situation)

Approach		Level of Service (LOS)			
From	To	(7:00-8:00) am	(8:00-9:00) am	(14:00-15:00) pm	(15:00-16:00) pm
WB	NB	F	F	F	F
	EB	F	F	F	F
	SB	A	A	B	B
NB	EB	F	F	F	F
	SB	F	F	F	F
	WB	C	C	D	D
EB	SB	E	F	F	F
	WB	E	F	F	F
	NB	D	E	F	F

Table B. Level of Service (LOS) for each approach (Alteration No.1)

Approach		Level of Service (LOS)			
From	**To**	**(7:00-8:00) am**	**(8:00-9:00) am**	**(14:00-15:00) pm**	**(15:00-16:00) pm**
WB	NB	F	F	F	F
	EB	E	E	F	F
	SB	A	A	A	A
NB	EB	E	F	F	F
	SB	E	F	F	F
	WB	B	C	C	C

Approach		Level of Service (LOS)			
		(7:00-8:00) am	**(8:00-9:00) am**	**(14:00-15:00) pm**	**(15:00-16:00) pm**
From	**To**				
EB	SB	D	E	F	F
	WB	D	F	F	F
	NB	C	D	F	F

Table C. Level of Service (LOS) for each approach (Alteration No.2)

Approach		Level of Service (LOS)			
		(7:00-8:00) am	(8:00-9:00) am	(14:00-15:00) pm	(15:00-16:00) pm
From	To				
WB	NB	E	F	F	F
	EB	E	E	F	F
	SB	A	A	A	A
NB	EB	E	F	F	F
	SB	E	F	F	F
	WB	B	B	C	C
EB	SB	C	E	F	F
	WB	D	E	F	F
	NB	B	C	E	F