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Evaluation and Improvement of Dallah Sahab Signalized Intersection in Amman City Using SIDRA Intersection Software

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Abstract

Computer simulation has become an important tool for evaluating transportation strategies quickly and efficiently. Simulation is especially critical in assessing the potential of innovative traffic control alternatives. The main objective of this study is to evaluate and improve at signalized Intersection in Amman City in Jordan. Dallah Sahab intersection was chosen for this study. The excessive traffic volumes, during the peak periods (in morning and evening), of vehicles that enter the intersection increase traffic density, reduce travel speed, increase travel time, and increase the delay values. In this study, the intersection will be analyzed using SIDRA INTERSECTION 5.0 software to evaluate the current situation and predicate the LOS, then suggest a suitable solution to make the intersection more efficient get a higher level of service, and reduce the delay will have proposed not for the current and design period. The operational analysis of the existing conditions of this intersection by SIDRA INTERSECTION 5.0 software indicates that the LOS of it equal to (E) with an intersection delay value of 65 sec/vehicle and a degree of saturation exceeds 1.0.

Keywords: Traffic Simulation Modeling, Level of Service, Delay, Signalized Intersection, SIDRA Software, Capacity, Traffic Operation.

Introduction

Transportation is very important in the day of our lives and its importance is summarized in searching for food or work, for trade or common, traveling for exploration, conquest, or personal need satisfaction. The highway mode of transportation has four main components: the driver, the pedestrian, the vehicle, and the road (Garber and Hoel 2014). It is essential to know the characteristics and the limitations of each of these components to provide efficient and safe highway transportation, it is also important to be aware of the interrelationships that exist among these components to determine the effects. Also, these characteristics are primarily important in traffic engineering measures such as traffic control devices. (Texas Department of Transportation 2021).

Traffic congestion has been increasing in many parts of the world, and it is a major issue in urban areas. traffic congestion is described by longer travel times, increased vehicular queueing, and Slower speeds (Bull and Cepal 2003). It happens when the traffic demand or volume exceeds the capacity of the roadway networks. Another cause of traffic congestion is road construction, weather events, and traffic incidents.

An intersection is defined as *"an area, shared by two or more roads, whose main function is to provide for the change of route directions. Intersections vary in complexity from a simple intersection, which has only two roads crossing at a right angle to each other, to a more complex intersection, at which three or more roads cross within the same area"*(Garber and Hoel 2014). Intersections are divided into three types: grade-separated with ramps (also identified as interchanges), at-grade, and grade-separated without ramps. Grade-separated intersections are typically made up of structures that allow traffic to cross at (vertical distances) different levels without being interrupted (Yue et al. 2019). The increase in traffic volumes and the resulting overcrowding at signalized intersections have been a challenge to transportation engineers in recent years. As a result, there has been a lot of interest in new designs that can handle high traffic loads at intersections (Hildebrand 2007).

One of the most effective ways of controlling traffic at an intersection is the use of traffic signals(Mathew 2012). Traffic signals can be used to eliminate many conflicts because different traffic streams can be assigned the use of the intersection at times. Since this results in a delay from vehicle to vehicle in streams, traffic signals must be used only when necessary. The average delay of all vehicles and the probability of crashes are the important criteria to evaluate the intersection efficiency (LOS) and the main objective of signal timing at the intersection to reduce it (He, Kamineni, and Zhang 2016).

Nowadays it is very common to see congestion at intersections during the morning and evening peak hours. Where traffic flow tends to be focused on one approach, a queue will form on the dominant approach which can affect the traffic flow and decrease the capacity of the intersection. The high volume of left-turning traffic is the primary cause of traffic congestion, which has an inverse impact on performance at signalized junctions. Many conventional methods, including optimization of signal timing, establishing double left-turn lanes, exclusive left-turning signals, grade separation, and enlarging intersections have been used to alleviate this problem, but their application is limited and expensive. As a result, there has been a lot of interest in finding new ways to enhance safety and performance at signalized arterial crossings with a lot of left-turning traffic (Naghawi, AlSoud, and AlHadidi, 2018).

Literature Review

Ali et al. (2018) employed computer simulation to examine travel time, wait time, saturation, service level, and travel speed at the Jordan crossroads in Baghdad, Iraq. The study documented the vehicular traffic volume at the crossroads between 7 am and 3 pm for four days. The simulation model evaluated the present performance, indicating a D level of service (LOS) with an average delay of 35 seconds per vehicle and a saturation degree of 0.996 vehicles per capacity unit. The study proposes that implementing an Intelligent Transportation System (ITS) to control traffic lights and closed circuit TV (CCTV) to detect congested areas could effectively alleviate traffic congestion.

Yasin et al. (2023) studied the Elba-house an intersection in Amman, Jordan, which is suffering traffic congestion as a result of a rise in both vehicle numbers and population. The objective of this study is to enhance the level of service and reduce delays by utilizing data obtained from traffic departments at the governorate level as well as field data. The intersection exhibits an F level of service with a total delay duration of 285.8 seconds. A tunnel and roundabout were suggested as measures to reduce the average wait and enhance service quality. Upon reanalysis, it was determined that the service level can be elevated to a grade of B, while simultaneously reducing the average delay to a duration of 13.3 seconds.

Maharjan and Marsani (2023) conducted the operational performance and prospective remedies for the Thapathali Intersection in the Kathmandu Valley, which is a significant junction connecting the city to Lalitpur. An extensive survey using camera footage was carried out for five days, which provided data on the highest traffic levels during peak hours. The results showed that on weekdays, the traffic volume reached 5,593 Passenger Car Units (PCU), while on weekends, it was somewhat lower at 4,883 PCU. Motorcycles accounted for 70.58% of the overall traffic. A traffic analysis software model was created and its effectiveness was assessed in scenarios where traffic was controlled by policing measures. There were six different models suggested, and the LC3-2 model was found to be the most suitable choice for weekdays, while the LC6-2 model was deemed the best option for weekends. The performance of the weekday model was assessed for a period of 3, 5, and 10 years, and it is projected to maintain a Level of Service (LOS) E until 2027. Similarly, the weekend model was tested and is expected to maintain LOS E until 2032.

(Gharaybeh et al. 2014) assess several traffic management scenarios to mitigate congestion in the vicinity of Yarmouk University, employing traffic simulation software. Information was gathered from eight prominent crossroads and examined at both the individual intersection and overall network levels. According to the findings, two unidirectional loops were the most optimal choice for five intersections and the second most optimal for three. The research at the sub-network level revealed that the presence of two interconnected rings of one-way streets resulted in the fastest average speed inside the sub-network and the lowest average delay caused by traffic congestion. The optimization of traffic lights did not result in significant benefits, however well-designed roundabouts with modest traffic loads have the potential to enhance network traffic performance.

Objectives

The main goal of this research is to study and analyze the operational performance of the Dallah Sahab Signalized intersection designs using the appropriate measures of effectiveness. The following individual objectives have been established to achieve the primary goal of the study:

1- Develop macroscopic simulation base models for the existing traffic conditions based on real traffic data to evaluate the conventional intersection designs using SIDRA simulation software.

2- Evaluate all proposals, that can solve the problem, of congestion at the Dallah Sahab intersection and calculate the level of service for proposals.

3- Select the best proposal that solves the congestion problem and provides a good performance within the design periods.

4- To make recommendations and conclusions to give the traffic management department suitable solutions.

Study Area

Dallah Sahab intersection is one of the main intersections of Amman, it links each of Sahab and Azraq streets. Sahab Street is a lanes divided arterial road with a posted speed of 65 km/h and Azraq Street is four lanes. Dallah Sahab intersection is a significant location and high traffic volume can be related to the important location and the existence of different public activities near Dallah Sahab intersection that result in a high delay at peak hour as shown in Figure 1.

Figure 1: Aerial View of the Selected Intersection. Source: (Google Earth Pro, 2023).

Data Collection

Traffic Volume

Traffic volume is one of the main variables that are in this study to measure the delay for each movement at the intersection, which collected from the Department of GAM, the peak period from 10:00 to 10. 59 AM where the intersection traffic volume is 15 minutes and the results for each movement for all directions EB, WB, and NB are as follows in Table 1 & Figure 3:

Table 1: Summary of traffic peak hourly volume for the intersections (veh/h)

Movement	Mawaqer Azraq street (EB)	Amman Azraq Street (WB)	Sahab Street (NB)
L	*	235	685
T	2850	1260	*
R	259	*	327

Existing Geometric Design

The evaluation of the existing level of service needs to specify the number of lanes in addition to the direction of each movement as shown in Figure 2.

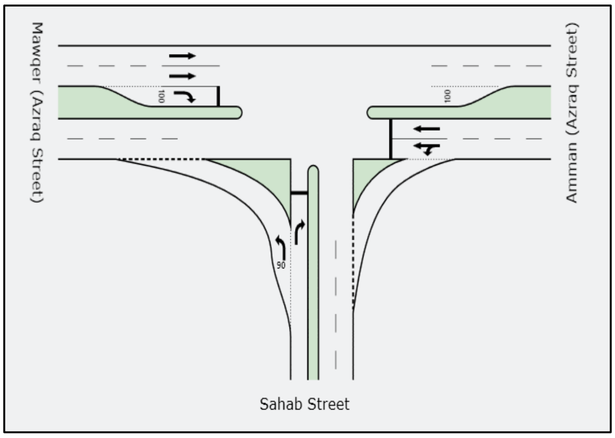

Figure 2: Existing geometric layout for Dallah Sahab intersection.

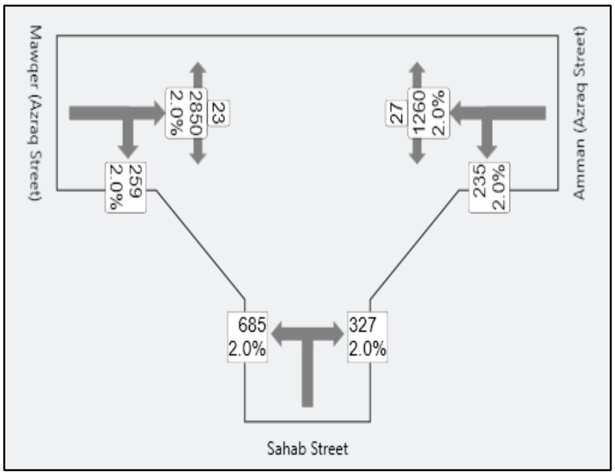

Figure 3: volume (vehicle & pedestrian) summary graph.

Traffic Controls Data

The phasing and timing data are specified per sequence i.e. different values of these data can be specified and saved for each and All-red time, cycle time option, actuated signal Data as summarized in Table 3. Figure 4 shows the flow chart of the methodology steps of the study.

Table 3: Controllers and Approach properties.

a-Type of controller	Pretimed
Number of phases	3 phases
Cycle length	100 seconds
Yellow time	4 seconds
All red time	2 seconds
b- Number of approaches	3 (EB, WB, NB)
Ideal saturation flow rate	1900 vph
Speed limit	60 km//h
Approach length	0.5km
Lane width	3.6 m

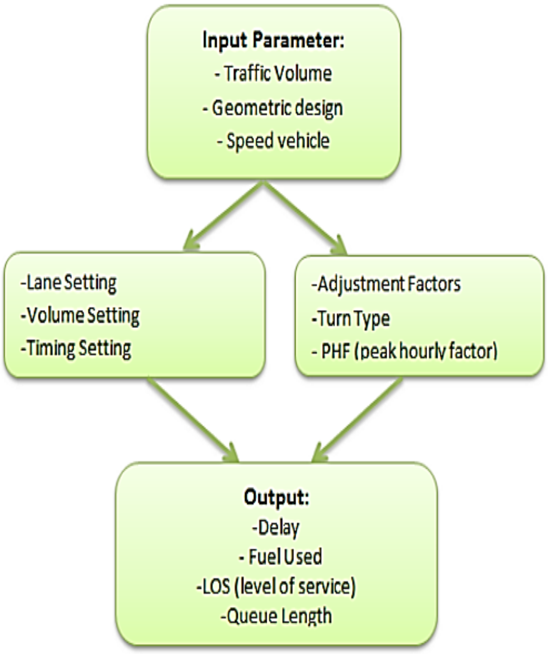

Figure 4: Methodology for signalized intersection operation analysis.

Analysis and Results

Results of the analysis are performed on existing traffic volumes and the existing geometric configurations of the Dallah Sahab intersection as represented in Figure 6 and Figure 7. Levels of Service (LOS) Criteria mended by the highway capacity manual are shown in Table 4. The results shown below indicate that the Dallah Sahab intersection operates under the level of service (D) with an average control delay of (65) seconds per vehicle during the peak hours studied as shown in Figure 5 and Figure 8. Also, the through movements from Sahab Street and the reverse movement operate with capacity constraints (LOS E) under existing traffic-volume conditions during peak hours.

Table 4: Level of Service (LOS) Criteria. (HCM, 2000)

Level of Service	Delay , (sec/veh)
A	≤10
B	> 10-20
C	> 20-35
D	> 35-55
E	> 55-80
F	> 80

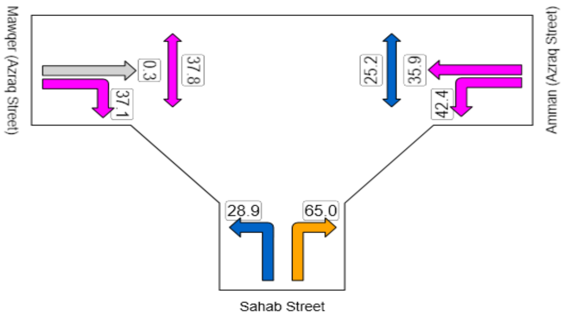

Figure 5: Delay of intersection (current situation).

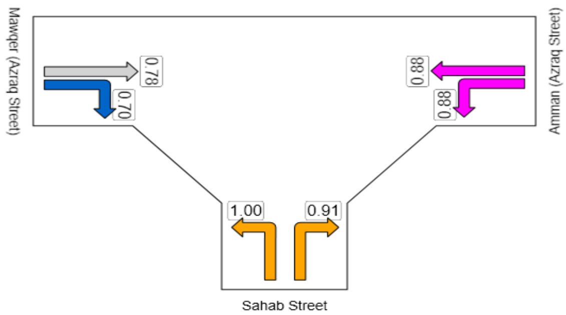

Figure 6: Degree of saturation (current situation).

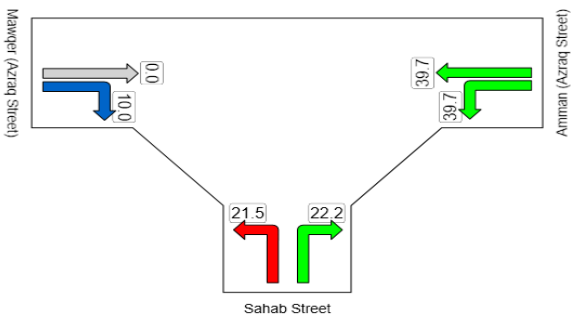

Figure 7: Queue length (current situation).

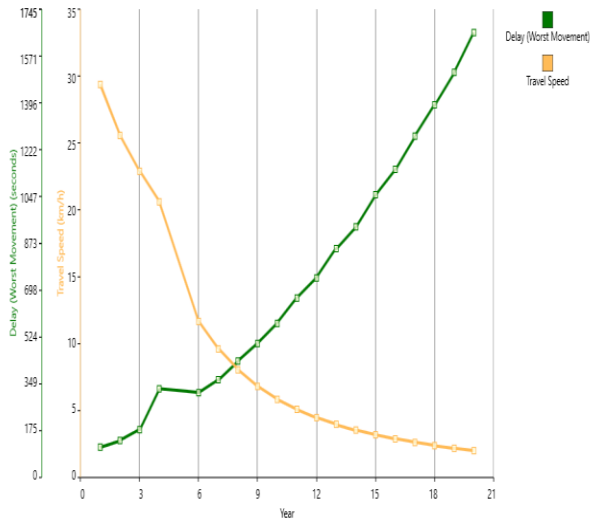

Figure (8): Delay & Travel time of intersection.

Model validation

Model validation is typically performed during the construction of the simulation model to assess the degree to which the model accurately represents reality. Simulation model validation can be achieved using two methods: visual inspection and statistical validation. The root mean square percent error (RMSPE) is the most widely used metric of goodness of fit. The RMSPE is employed to quantify the error as a percentage rate (Ni et al. 2004). The RMSPE can be calculated using the following equation:

$$\text{RMSPE}=\sqrt{\frac{1}{N}\sum\left(\frac{\text{Y sim-Yobserved}}{\text{Y sim}}\right)^2} \text{ ……… Eq.1}$$

Where:

N: the number of simulations Runs.

Y_{sim}: the simulation runs throughput volume.

$Y_{Observed}$: the real throughput volume.

Table 5: simulation and observed volumes & RMSPE calculations.

Approach	Observed volume |(veh/hr)	Simulation volume (veh/hr)	$(\frac{Y\ sim - Yobserved}{Y\ sim})^2$
NB	1012	1065	0.00248
WB	1495	1573	0.00246
EB	3109	3273	0.00251
Summation			0.00745
RMSPE			0.0386

Based on Eq. (1) the RMSPE was found to be 0.0386 this value is less than 0.15 which is the RMSPE threshold. This indicates that the model replicates reality with high accuracy (Hourdakis and Michalopoulos 2002).

The suggested improvement

After considering the future traffic volumes for the different movements in the Dallah Sahab intersection and the availability of free land within the intersection area which can be used in the overpass construction to reduce the traffic through movement in Sahab Street, the proposed geometric design for the Sahab Bridge represents the unique solution to improve the performance of the intersection after m considering the restrictions mentioned above. To evaluate the performance of the overpass after considering the proposed geometric design, signal phasing plan, and the design year (2040) traffic volume, operational analysis is performed using the highway capacity SIDRA Software, and the summary of results is shown in Table .5 below. The results indicate that the interchange will operate under the level of service B in the design year with an average delay value 20 times less than what exists now before intersection geometry modification.

Recommendation

Based on the results of the present work, the concerned authorities have to improve the signal timing of the signalized intersections by setting the required time per approach based on its demand, to improve the level of service of the network. Bridges are one of the effective ways to eliminate the congestion. Therefore, it is suggested to construct a bridge in the east-west direction of the analyzed direction, as the level of service is very poor in this direction.

Conclusion

It has been concluded that optimization or adding an extra lane for through or left movement at the Dallah Sahab intersection isn't the best proposal to improve the capacity and traffic operation in the Dallah Sahab intersection. Median U-Turns one of the Unconventional ways should be installed in the West-East direction (Amman street) since the traffic survey shows that the high traffic volume of the left movement in the West-East direction has a major effect on the intersection to improve the LOS and capacity of the intersection**.**

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Appendix 1

- **The operational analysis results for the existing condition of the Dallah Sahab intersection.**

Movement Performance - Vehicles												
Mov ID	Turn	Demand Flow veh/h	HV %	Deg. Satn v/c	Average Delay sec	Level of Service	95% Back of Queue Vehicles veh	95% Back of Queue Distance m	Prop. Queued	Effective Stop Rate per veh	Average Speed km/h
South: Sahab Street											
1	L	699	2.0	1.000[3]	28.9	LOS C	21.5	153.1	0.85	0.97	34.9
3	R	366	2.0	0.909	65.0	LOS E	22.2	158.4	1.00	1.01	22.1
Approach		1065	2.0	1.000	41.3	LOS D	22.2	158.4	0.90	0.98	29.1
East: Amman (Azraq Street)											
4	L	247	2.0	0.878	42.4	LOS D	39.7	282.5	0.96	1.09	29.2
5	T	1326	2.0	0.879	35.9	LOS D	39.7	282.5	0.97	1.03	29.1
Approach		1574	2.0	0.879	36.9	LOS D	39.7	282.5	0.97	1.04	29.1
West: Mawqer (Azraq Street)											
11	T	3000	2.0	0.779	0.3	NA[3]	NA[3]	NA[3]	NA[3]	0.00	59.4
12	R	273	2.0	0.703	37.1	LOS D	10.0	70.9	0.98	0.91	29.7
Approach		3273	2.0	0.779	3.4	LOS A	10.0	70.9	0.08	0.08	54.9
All Vehicles		5912	2.0	1.000	19.2	LOS B	39.7	282.5	0.47	0.50	39.3

- **The volume data summary.**

Volumes						
To Approach	Total veh	HV %	Peak Flow Factor %	Vehicle Occupancy pers/veh	Flow Scale %	Growth Rate %/year
From: South Sahab Street						
West	685.0	2.00	95.0	1.10	100.00	5.00
East	327.0	2.00	95.0	1.10	100.00	5.00
From: East Amman (Azraq Street)						
South	235.0	2.00	95.0	1.10	100.00	5.00
West	1260.0	2.00	95.0	1.10	100.00	5.00
From: West Mawqer (Azraq Street)						
East	2850.0	2.00	95.0	1.10	100.00	5.00
South	259.0	2.00	95.0	1.10	100.00	5.00

Appendix 2

- **The approach lane data.**

Geometry - Approach Lane Data - Signalised												
Lane Number	Lane Type	Lane Discip.	Basic Satn Flow tcu/h	Utilisation Ratio %	Saturation Speed km/h	Capacity Adjustment %	Buses Stopping veh/h	Parking Man. veh/h	SL Green Constraint	Free Queue L veh	T veh	R veh
South Sahab Street												
App. Lane 1	Slip (Giveway/ Yield)	L	1950	-	-	0.0	-	-	No	0	0	0
App. Lane 2	Normal	R	1950	-	-	0.0	-	-	No	0	0	0
East Amman (Azraq Street)												
App. Lane 1	Slip (Giveway/ Yield)	LT	1950	-	-	0.0	-	-	No	3	2	0
App. Lane 2	Normal	T	1950	-	-	0.0	-	-	No	0	0	0
West Mawqer (Azraq Street)												
App. Lane 1	Continuous	T	1950	-	-	0.0	-	-	No	0	0	0
App. Lane 2	Continuous	T	1950	-	-	0.0	-	-	No	0	0	0
App. Lane 3	Normal	R	1950	-	-	0.0	-	-	No	0	0	0

Geometry - Approach Data						
Location	Name	Type	No. of App. Lanes	No. of Exit Lanes	Median Width m	Extra Bunching %
South	Sahab Street	Two-way	2	2	2.00	0.0
East	Amman (Azraq Street)	Two-way	2	3	2.00	0.0
West	Mawqer (Azraq Street)	Two-way	3	2	2.00	0.0