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Original Research

ASSESSMENT OF SIGNALIZED INTERSECTION: A CASE STUDY IN BAGHDAD City by USING SIDRA SOFTWARE

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Abstract: Over the world, signalized intersections and road networks with heavy traffic have posed severe issues. So, it is crucial to employ cutting-edge software tools to ensure the current system can be managed and assessed. Therefore; this paper aims to analyze and evaluate the traffic flow performance at AL-Masbah signalized intersections in Baghdad city during peak hours by utilizing SIDRA INTERSECTION 5. For purposes of evaluation, the Level of Service LOS, average delay time, capacity, degree of saturation, queue for Intersection, fuel consumption, and carbon dioxide emission have been considered. In this study, video count was used to collect data. The main input data included peak hour factor (PHF), numbers and width of lanes, percent of heavy vehicles for each direction and movement, median, phasing, and timing. The results of the analysis indicated that the intersection is operated at LOS (F) with a backlog queue of 166.1 which is the queue for any lane used by movement (vehicles)and a 1262m queue for any lane used by movement (meters) m, while fuel consumption was at a rate of 849.9 liters per hour. Furthermore, the results revealed that carbon dioxide (CO_2) emission was increased by 2124.8 Kg per hour. So, It can be concluded that the intersection needs to improve its level of service by changing its geometry or by implementing an Intelligent Transportation System (ITS).

Keywords: *Delay; level of service; signalized intersection; SIDRA; sustainable urban transportation*

1. Introduction

Traffic congestion is a major sociological and economic issues in urban areas related to the transportation sector, in both developed and developing nations. Traffic jams are often seen near intersections and are terrible during rush hour [1-2]. The road network's intersections, where traffic from various directions crosses each other, play a significant role in the efficiency of road networks in urban areas as they are the main bottlenecks in the system. The intersection design process is not easy because there are many factors related to operational efficiency such as delay, absorptive, and emissions from vehicles in addition to safety and geometrical constraints. Failure to design a proper intersection leads to many problems, including increased accidents, congestion, and environmental pollution resulting from vehicles. Researchers and vehicle makers aspire to keep road users safe, reduce costs, and maintain driver comfort [3-4].

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Moreover, the degree of service at the intersection greatly impacts the road's total level of service [5]. Increasing the intersection's capacity is essential for expanding any road's carrying capacity. Traffic jams, an increase in vehicle emissions, and traffic accidents may all be caused by poorly constructed intersections. The current road, traffic, and control circumstances significantly impact how effectively junctions operate. Vehicle emissions have also been a significant consideration in intersection design in recent years. Environmentally friendly options are more crucial than ever to reducing the transportation sector's contribution to global warming [6-9]. The signalized phases may occasionally need to be altered to preserve operational dependability owing to traffic demand, particularly in developed areas [4]. The type of control used at crossings significantly impacts any urban corridor's functionality. To choose the optimal sort of control, a variety of established methods are available to calculate some of the key operational variables, including capacity, delay, and level of service [3]. Although they are not fully addressed, other significant issues, such as the effect of emissions, have an impact on the operational features of major arterials [7]**.** For example, vehicle emissions levels at various junction types (roundabouts and signalized intersections) to determine which style of junction is most effective and should be used in the city for a healthier traffic environment. For that, SIDRA software was used to assess the value of carbon monoxide (CO), carbon dioxide (CO2), hydrocarbon (HC), and nitrogen oxide (NOx) for vehicular traffic during morning and afternoon peak hours at both junction types [10-11]. At an intersection, a study of the volume of traffic and a survey of geometrical aspects were done. The human traffic count method was used for the traffic volume study, and tape and a total station were used for the geometry survey, which quantified the number, movement, and type of vehicles at this intersection. The ideal cycle length and signal setting were found using SIDRA Intersection software and the intersection's maximum average passenger car unit [12]. Joni and Mohammed [13] used SIDRA to analyze operational traffic flow in the Al-Masbah Intersection. They concluded that SIDRA software has good outcomes for analyzing delay, flow, queue, and capacity. Jameel [3] and Omar and Hussein [14] applied Highway Capacity Software (HCS) and SIDRA software to enhance the performance of signalized intersections in Baghdad and Erbil cities respectively. They found that there is a 21% reduction in the value of average delay when using STDRA delay model, while it is reduced by 29% when using HCS. Also, the results revealed that the SIDRA model has a lower optimum cycle time as compared with HCS. Ahmida et al. [15] performed an enhancement to five intersections after evaluating their performance by using SIDRA software. The results revealed that the reduction in the value of average time delay could enhance traffic flow, decrease travel time, and increase speed, consequently reducing in consumption of fuel and pollution (CO2) emissions. Zubaidi et al. [16] investigated the factors that can influence crashes at roundabouts. They concluded that most of injury crashes are related to the characteristics and behavior of drivers. This conclusion has been supported in other studies [17-19]. Aboud et al. [20] utilized SIDRA software to evaluate cost, travel time delay, and carbon dioxide emission. The researchers concluded that there is an improvement in the LOS from E and F to C and a reduction in travel time, cost, and pollution emission by 16%, 25%, and 29% respectively when using gas power cars, modern private car and different types of cars for public transport. This has been considered a step to further studies on sustainable transport [21]. Makino et al. [22] showed that some cities are using modern information and communication technologies to solve their urban traffic problems using intelligent transport systems (ITS), and some of these cities have had success with the installation of these systems. Akcelik and Associates Pty Ltd. created software called SIDRA Intersection signalized and unsignalized Intersection design and Research Aid is the abbreviation for this study [23]. SIDRA is renowned for having benefits over other software models when comparing the efficacy of various types of intersections. This has been the base of further studies in the ITS [24-26].

SIDRA is a micro-analytical program that is frequently used in traffic engineering to analyze various intersection types of lane by lane. It estimates effectiveness measures (MoE) such as intersection capacity, overall delay, queue lengths, and pollution levels by combining traffic models with an iterative approximation method [27]. SIDRA has been utilized in the majority of investigations on the effectiveness of intersection operations. The consistency of capacity and performance analysis is emphasized by SIDRA's techniques [28].

2. Aims of the Study

The Al-Masbah Intersection is considered one of the most heavily trafficked and strategically important crossroads within the traffic network of Baghdad City. This intersection will undergo thorough analysis and assessment by applying SIDRA INTERSECTION 5 Software as a vital component of this research. This research aims to analyze and evaluate the traffic flow performance at AL-Masbah signalized intersections in Baghdad city during peak hours.

3. Methodology and Study Area

To assess the state of the city's traffic system at the time, the study concentrated on how traffic moved through signalized intersections. SIDRA INTERSECTION 5 Software was used to analyze and evaluate the traffic flow's performance. In addition, data about volumes of traffic which included type of vehicles such as cars, buses, trucks, vans, and motorbikes, as well as the geometric design of crossings and the phases movement of intersections for cycle times, were gathered for the field after observation and site selection. In addition to avoiding extreme weather and natural traffic conditions, the amount of traffic, which is the most important factor when it was gathered, must be collected during typical working days when crashes occur.

Al-Karada Street is one the most important and longest streets in Baghdad city which is located on the Al-Karkh side of the Tigris River. The so-called Khalid Bin Al-Waleed Street, which runs from the intersection of the Masbah (German Embassy) to the University of Baghdad, where it directly connects to the Great Jadriya Bridge linking Karkh Baghdad and Rasafa and passes in front of the University of Baghdad, which is parallel to the streets (Karada in Abu Nwas North and the Sada street south), It is one of the longest commercial streets in Baghdad, with many shops and important government buildings. Fig. 1 illustrates the geometry of the study intersection with several intersections that intersect it. The dimensions of cross-sectional components of highways such as shoulders at crossings, median width, and length were specified from the field in addition to the traffic signals and numbers of lanes.

3.1. Data Collection

Data collection is a critical step in the analysis process. Knowing what to collect, when to collect, how long to collect, where to collect, and how to manage the data must be addressed before starting the collection. In this study, video count was used.

Figure1. Satellite Image for the Study Area

The counting of traffic volumes classified by movements was conducted manually for the four approaches in an average of seven days in good weather conditions starting on 15-1-2023. The traffic volumes for the counting period were recorded for every 15 minutes to calculate the peak hour factor at each approach (from The National Theatre, From Al-huraya Intersection, From Al-masbah Street, and from Aqba Bin Nafi intersection). Table 1 shows the traffic volumes at each approach for the intersection and Fig. 2 represents total traffic volumes from Sunday to Thursday.

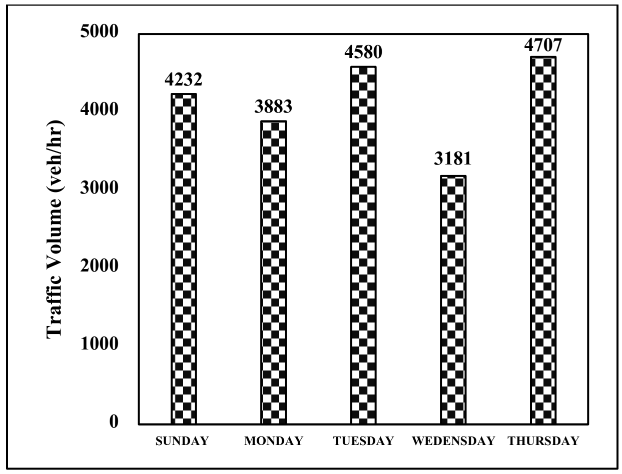

Figure 2. Total Traffic Volumes in the Study Area

Table 1. Traffic volumes for AL-Masbah Intersection

Day	Time	From The National Theatre			From Al-Hurya			From Al-Masbah Street			From Aqba Bin Nafi		
		R	TH	L	R	TH	L	R	TH	L	R	TH	L
Sunday	12:00-12:15	51	153	56	31	196	198	30	103	50	27	164	69
	12:15-12:30	36	138	24	17	136	155	34	70	47	11	121	67
	12:30-12:45	37	208	36	24	178	171	27	106	49	12	159	72
	12:45-1:00	49	213	41	22	171	182	30	117	64	24	166	90
Monday	12:00-12:15	32	172	38	36	155	148	26	92	39	19	132	53
	12:15-12:30	29	169	31	19	146	162	28	88	43	14	135	62
	12:30-12:45	38	188	51	31	137	163	29	78	46	36	144	67
	12:45-1:00	24	143	42	24	172	169	35	93	62	21	167	72
Tuesday	12:00-12:15	28	142	57	50	228	210	39	116	71	34	171	75
	12:15-12:30	30	165	29	24	140	163	36	73	68	11	118	71
	12:30-12:45	36	213	43	44	184	188	38	113	66	20	195	74
	12:45-1:00	33	185	52	33	204	203	31	156	81	27	193	92
Wednesday	12:00-12:15	19	97	41	17	128	113	23	78	28	16	119	41
	12:15-12:30	24	129	32	21	131	119	31	66	37	22	121	35
	12:30-12:45	27	171	34	32	126	151	17	73	42	19	134	48

	12:45-1:00	23	131	42	16	158	163	27	76	53	25	157	64
Thursday	12:00-12:15	51	164	54	15	112	158	29	98	45	23	134	72
	12:15-12:30	45	182	46	22	184	229	31	112	55	17	156	83
	12:30-12:45	44	191	65	29	189	189	36	123	64	27	165	91
	12:45-1:00	41	211	41	32	201	233	43	141	73	23	173	89

3.2. Main Input and Output Data of SIDRA Software

The main input data that were required by applying SIDRA program included: peak hour factor (PHF), numbers and width of lanes, percent of heavy vehicles for each direction and movement, median, phasing, and timing.

It is important to mention that the traffic volumes were collected for every direction (north, south, east, and west) and all movements (through, right, and left), and all the traffic volumes were in the passenger car unit. Heavy vehicles (all lorries and Buses) multiplied by 2.2 and motorcycles by 0.35 it is a system utilized by Britain to convert various types of vehicles. There are three lanes for each direction, the width of lane 3.2 m and median width of less than 1 m (0.9m) for the directions Almasbah and National Theater and 1.5 m for Aqba Bin Nafi and Al-Hurya

Furthermore, the main output data were average delay, capacity, degree of saturation, and level of service (LOS). Also, backlog queues, fuel consumption, and carbon dioxide (CO_2) emissions can be obtained.

4. Analysis and Results

Traffic volumes were collected for (Sunday, Monday, Tuesday, Wednesday, and Thursday) for the peak hour from (12:00 pm to 1:00 pm). It is worthwhile to mention that after conducting a comprehensive study of traffic volumes in the study area, which lasted for a month, it was noted that the maximum traffic volumes were from twelve to one o'clock in the afternoon. For this reason, this period was chosen when conducting traffic volume calculations.

The results of the analysis indicated that the level of service was F for all directions, and the backlog queue was 166.1 which was the queue for any lane used by movement (vehicles)and 1262m queue for any lane used by movement (meters), while an average delay and losses in cost were 245 seconds per vehicle and 5448.3 cent respectively. Moreover, the results revealed that CO2 emission was 2124.8 kg/ hr and fuel consumption was 849.9 liter per hour.

Table 2 and Fig. 3 represent the phasing time for Intersection on Thursday.

Table 3 shows the output of the software and Fig.4 illustrates the LOS.

Table 2. Phase Timing For Intersection

phase	Phase time (Sec)	phase spilt
A	46	17%
B	60	22%
C	103	38%
D	61	23%

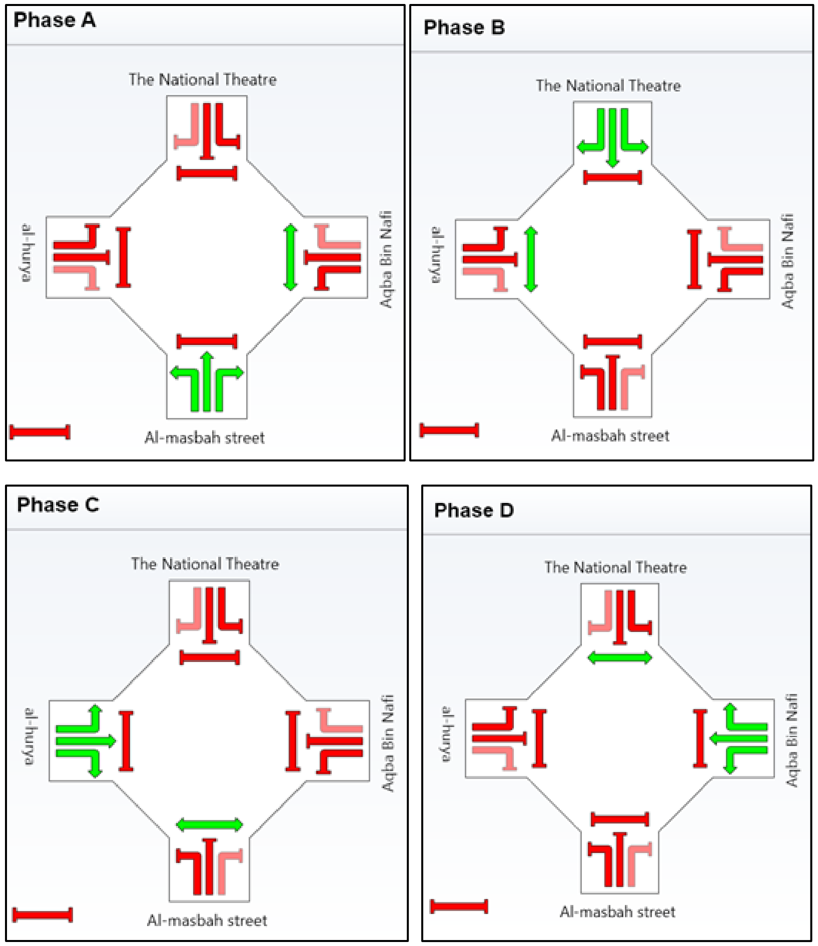

Figure 3. Phasing Time For The Intersection

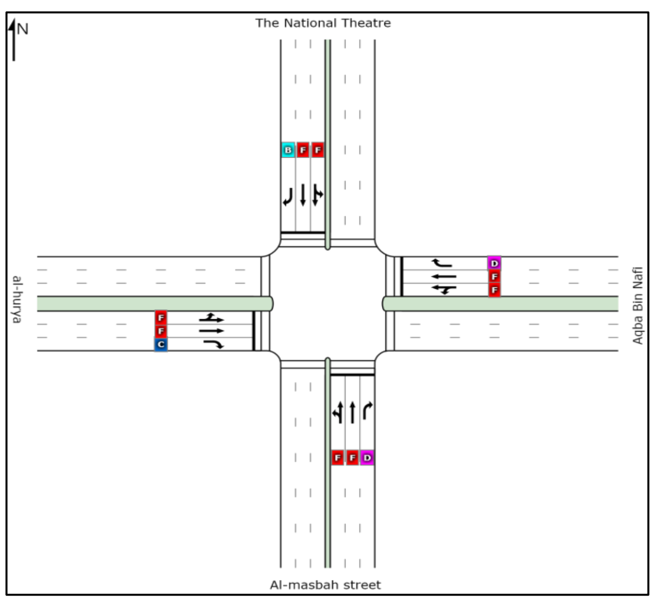

Figure4. Level of service for intersection (Thursday)

Table 3. Output of SIDRA Software

Lane Use and Performance

	Demand Flows				HV	Cap.	Deg. Satn	Lane Util.	Aver. Delay	Level of Service	95% Back of Queue		Lane Length	SL Type	Cap Adj.	Prob. Block
	L veh/h	T veh/h	R veh/h	Total veh/h	%	veh/h	v/c	%	sec		Vehicles veh	Distance m	m		%	%
South: Al-masbah street																
Lane 1	258	122	0	380	0.0	274	1.385	100	308.1	LOS F	72.8	553.5	500	–	0.0	14.2
Lane 2	0	393	0	393	0.0	284	1.385	100	307.5	LOS F	75.3	571.9	500	–	0.0	17.2
Lane 3	0	0	151	151	0.0	637	0.237	100	35.5	LOS D	11.0	83.5	500	–	0.0	0.0
Approach	258	515	151	924	0.0		1.385		263.3	LOS F	75.3	571.9				
East: Aqba Bin Nafi																
Lane 1	364	150	0	514	0.0	372	1.383	100	294.8	LOS F	98.0	744.9	500	–	0.0	41.5
Lane 2	0	532	0	532	0.0	385	1.383	100	294.3	LOS F	101.4	770.8	500	–	0.0	44.7
Lane 3	0	0	98	98	0.0	624	0.157	100	41.7	LOS D	7.4	56.5	500	–	0.0	0.0
Approach	364	683	98	1145	0.0		1.383		272.9	LOS F	101.4	770.8				
North: The National Theatre																
Lane 1	224	289	0	513	0.0	370	1.385	100	296.4	LOS F	97.9	743.7	500	–	0.0	41.3
Lane 2	0	524	0	524	0.0	378	1.385	100	296.1	LOS F	100.0	759.7	500	–	0.0	43.3
Lane 3	0	0	135	135	0.0	836	0.161	100	17.1	LOS B	6.8	52.0	500	–	0.0	0.0
Approach	224	813	135	1172	0.0		1.385		264.1	LOS F	100.0	759.7				
West: al-hurriya																
Lane 1	879	0	0	879	0.0	637	1.381	100	266.5	LOS F	166.1	1262.2	1000	–	0.0	26.2
Lane 2	0	746	0	746	0.0	669	1.115	81	156.3	LOS F	122.0	927.0	1000	–	0.0	0.0
Lane 3	0	0	107	107	0.0	849	0.125	100	20.0	LOS C	5.8	43.7	500	–	0.0	0.0
Approach	879	746	107	1732	0.0		1.381		203.9	LOS F	166.1	1262.2				
Intersection				4972	0.0	1.385			245.0	LOS F	166.1		1262.2			

4.1. Saturation of Flow

Due to its immediate impact on the average delay of the intersection, which serves as an indicator of the level of service for intersections, the saturation of flow for each path is considered to be one of the huge and delicate factors in this investigation. This is due to the planning of specialized information that is necessary for the theoretical computation. To calculate the saturation flow for each lane in each path using Webster's approach [27]. Table 4 shows the degree of saturation flow for Al-Masbah intersection.

Table 4. Degree Of Saturation Flow For AL-Masbah Intersection

Degree of Saturation	From The National Theatre			FromAl-Hurya Intersection			FromAl-Masbah Street			FromAqbaBin Nafi Intersection		
	R	TH	L	R	TH	L	R	TH	L	R	TH	L
	1.385	1.385	1.161	1.381	1.115	1.381	1.385	1.385	0.237	1.383	1.383	0.157
Intersection		1.385			1.381			0.92			1.383	

4.2. Delay, LOS, Queue, Fuel, and CO2 for Intersection

The delay at a signalized intersection is the difference between a vehicle's arrival and departure times at the intersection. It is also known as the excess time a vehicle spends at an intersection compared to what would be necessary if all traffic were allowed to pass through the intersection without any delays.

Table 5. Level of Service Definitions Based on Delay [29]

Level of Service (LOS)	Control Delay per Vehicle in Sec
A	d≤10
B	10 <d < 20
C	20 <d < 35
D	35 <d < 55
E	55 <d < 80
F	80 <d

Table 6. Average Delay and LOS for Intersection

Delay (Average)	From The National Theatre	From Al-Hurya Intersection	From Al-Masbah Street	From Aqba Bin Nafi Intersection	Intersection
	264.1	245	263.3	272.9	245
LOS	F	F	F	F	F

According to the Highway Capacity Manual (HCM) [29], the LOS is divided into six types each of which is based on the average delay as shown in Table 5. To evaluate the LOS for the current situation, the mean delay at Al-Masbah intersection was calculated.

The Highway Capacity Manual and SIDRA Software confirm that the Al-Masbah intersection will operate in LOS F, with an average delay of 245 seconds per vehicle as depicted in Table 6. The performance of traffic flow will be evaluated based on its level of service, delay, travel speed, performance index, operational cost, fuel consumption, and carbon dioxide emission. The results showed that the level of service was extremely low, causing slow speeds and severe delays during peak hours. Results in Table 7 show that the backlog queue was 161.1veh and queue distance 1262 m, while fuel consumption was at a rate of 849.9 liters per hour. Furthermore, the results revealed that carbon dioxide CO_2 emissions were increased by 2124.8 kg per hour.

Table 7. Queue, Fuel, and CO2 for Intersection

	South	**East**	**North**	**West**	**Intersection**
Queue Movement (veh)	75.3	101.4	100.0	166.1	166.1
Queue Distance (m)	572	771	760	1262	1262
Fuel (liters per hour)	163.8	208.4	208.9	268.7	849.9
CO2 (kg/hr.)	409.6	521.0	522.4	671.8	2124.8

5. Conclusions

The main conclusions drawn from the analysis of the AL-Masbah Intersection by SIDRA software are presented as follows.

The level of service was extremely low (LOS F), where the flow is forced or broken down at this level and with generally more demand than capacity. Since the level of service was F, therefore a backlog queue of 166.1 veh and 1262 m were formed with an average delay of 245 sec/veh. Due to the delay that is anticipated at LOS F, therefor; pollution levels especially carbon dioxide emission have increased to reach 2124.8 kg/hr, while fuel consumption was 849.9 liters /hr.

To create a sustainable urban transportation system, improve the traffic situation, and reduce congestion and pollution resulting from it, the study recommends the following,

Increase public transportation options: Expand bus and rail networks, create bike-share programs, and make public transportation more accessible to all.

Develop walkable communities: Create pedestrian-friendly streetscapes with sidewalks, crosswalks, and bike lanes.

Promote carpooling: Encourage people to share rides with others to reduce the number of cars on the road.

Invest in electric vehicles: Provide incentives for people to purchase electric vehicles and install charging stations in public places.

Implement congestion pricing: Charge drivers a fee for using certain roads during peak hours to reduce traffic congestion.

Increase access to alternative fuels: Make alternative fuels such as biodiesel or natural gas more widely available for vehicles that use them.

Educate the public about sustainable transportation options: Raise awareness about the benefits of sustainable transportation options and encourage people to use them whenever possible.

Conflict of interest

The authors declare that there are no conflicts of interest regarding the publication of this manuscript.

Author Contribution Statement

The first author proposed the research problem and developed and applied the methodology.

The second and third authors supervised the findings of this work and contributed to writing the paper.

The first and fifth authors discussed the results and contributed to the final manuscript.

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