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Performance Evaluation and Improvement of Main Road Intersections in Al-Bayda City Using Sidra Software

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Abstract: Intersections are one of the most crucial parts of urban transportation systems since they actively contribute to developing strategies to reduce traffic congestion. Congestion is one of the major issues that intersections face as a result of the growth in traffic, which cause lower service levels and longer waiting time. The main goal of this study was to evaluate the current traffic flow and Level of Service (LoS) at four signalized intersections at peak hours in the city of Al-Bayda utilizing sidra software. In addition, comparing the performance of traffic flow during the morning and evening peak hours at the selected intersections. The results revealed that the level of service of the four intersections was very low and ranged between F and D, which indicated that the delay time was very high, therefore, an improvement to these intersections was necessary. After exploring various alternatives, the level of service increased to B and D levels, which make the delay time acceptable in these intersections. In the morning period, the average delay time decreased by 43.6, 44.3, 32.3, and 42% for intersections no.1-4 respectively. In the evening period, the average delay time decreased by 45.8, 69.5, 57.5, and 52% for intersections no.1-4 respectively.

Keywords: Transport Networks, Traffic Volume, Level of Service, Delay Time, Sidra Software

Introduction

The world's urban communities rely heavily on their transportation systems to support their economies and make it easy for people to move around and support their daily activities (Chiguma, 2007). Many engineers and designers in the field of transportation, urban design, and traffic systems have turned to the use of computer simulation as a result of technological advancement nowadays. With the aid of engineering programs, the designers are able to estimate the level of service and delay time and anticipate future transport volumes and congestions, which allows the designer to test a wide range of solutions and operational conditions and search for the best solutions and alternatives (Yahia, 2017). One of the major issues that nations around the world face is traffic congestion on roads and intersections. Traffic congestion at intersections is a result of poor road network design strategies which, frequently causes delays and increases travel times during regular and peak hours. To regulate the traffic flow at intersections, many techniques are usually adapted, namely, turn islands, traffic signals, and stop and yield signs (Albrka *et al*., 2014). The HCM (Manual, 2000) defines capacity as the highest hourly pace at which individuals or vehicles can be expected to travel a specific distance or uniform segment of a road in a specific amount of time. The time frame during which the current traffic, road, and control circumstances predominate. In addition to any prevailing circumstances, indicate the intersection's circumstances right now (Manual, 2000).

A vehicle's delay at an intersection is measured in terms of how much longer it would take to pass if there were no obstruction. Delay is defined in slightly different ways by various academics. It is crucial that the modeler (user of the software) understands the type of delay that the model predicts. Control delay and geometric delay are the two types of delays in HCM (Manual, 2000). Delay is referred to as geometric delay and stop line delay. Control delay is the total of geometric delay and stop line delay. Traffic signals are used to increase abilities to cope with controlled traffic at intersections while also ensuring safety and efficient traffic flow. Traffic signals also decrease rotation speed, accidents, and traffic delays (Manual, 2000; Al-Omari and Ta'amneh, 2007; Taale and Van Zuylen, 2001; Akcelik and Besley, 2003; Abd-Allah *et al*., 2020).

Sidra and transyt-7f programs were among the traffic simulation optimization programs which used to evaluate the performance of traffic flow in many cities around the world. It was found that, the software provided satisfactory alternatives to improve the traffic flow at the selected intersections and roundabouts. The optimization of the intersections and roundabouts, showed a reduction in the average delay time, fuel consumption, and increase travel speed (Ali *et al*., 2018; Irtema *et al*., 2015; Albrka *et al*., 2014). Significant social, economic, and environmental consequences are associated with traffic congestion since road intersections are the main cause of traffic congestion, subsequently, they are the main source of the traffic flow to the main and secondary roads, hence the improvement in the traffic flow through the intersections is essential to improving the traffic flow in the whole transportation system (Abdallatef *et al*., 2019; Ranjitkar *et al*., 2014).

The Australian Road Research Council (ARRB) developed the sidra software, which is an abbreviation for signalized and unignalized intersection design and research aid (Albrka *et al*., 2014). Sidra is a micro-analytical software that is commonly used in traffic engineering for a lane-by-lane analysis of different intersection types with timing, amplitude, performance, and signal analysis for isolated intersections (Al-Omari and Ta'amneh, 2007). Abd-Allah *et al*. (2020) concluded that sidra Software is considered the best software among the three software programs tested for prediction of the field delay times at signalized intersections after the calibration process. The design and evaluation of signaled intersections (fixed, pre-time, and active), signaled pedestrian crossings, turn islands, one-point intersections, and two-way stop sign control are aided by the use of the sidra intersections program. The program's adaptability enables it to be used in a variety of additional circumstances, such as those involving continuous traffic flow and integrated analysis (Taale and Van Zuylen, 2001). In order to produce estimates for capacity and performance data, sidra intersections, considered as reliable traffic analytical assessment tool, employs lane-by-lane and driving cycle models as well as an iterative approximation method (delay, queue length, stop rate, etc.,) (Akcelik and Besley, 2003).

The average total delay of all vehicle movements through a signaled intersection (LoS) is used to calculate the level of service. Car lag is a method for calculating some intangible factors and circumstances, such as wasted travel time, discomfort, and driver irritability. The assessment of vehicle delay is a difficult procedure that depends on a number of factors, including the number of signal phases, the volume of traffic, the capacity of intersections, and rotation islands. According to the sidra intersection 5 manual, Table 1 displays the service level for a signalized intersection (Akcelik and Besley, 2003).

The main objective of this study is to evaluate traffic flow performance at four signalized intersections in Al-Beyda city, Libya. The existing level of service at the selected intersections is used to evaluate the traffic. Finally, based on the analysis using sidra software, some solutions are proposed to improve the traffic flow at these intersections.

Problem

After the uprising and the war in Libya, many cities received unexpected movements of citizens from different regions. The city of Al-Bayda, located in the east of Libya, is one of the cities that experienced an increase in commercial and residential activities as well as a movement of people from other cities and regions around the country of Libya. This has resulted in a significant increase in the number of vehicles and an increase in traffic volume, which has caused traffic jams at the main road intersections in the city.

The selected intersections are the four main intersections that run through the heart of Al-Bayda city and they are experiencing heavy traffic flow and there are many activities located around these intersections Fig. 2. The intersections have median islands and are four legged, bidirectional intersections.

The first intersection (the western entrance to the city) and its coordinates (568364.05 E, 3624622.64 N): Designated as intersection No.1 throughout the paper, it connects the city's center with the western entrance, as well as the industrial district to the south, Omar Al-Mukhtar University to the west and the highway road to the north. Because of its location this intersection experiences intense daily traffic.

The second intersection (known as the intersection of the commercial bank) and its coordinates (569346.07 E, 3625061.51 N): Designated as intersection No.2, it links the city's center and the industrial district to the south, the secretariat complex to the north, followed by Al-Orouba street to the east, Omar Al-Mukhtar University and the city's western entrance to the west.

Table 1: level of service definition based on delay time only (for vehicles), (Manual, 2000)

	Control delay per vehicle in second (d)		
Level of service	Signals (sidra standard default for roundabouts)	"Sidra roundabout LoS" option	Sign control
A	d ≤10	d ≤10	d ≤10
B	10< d ≤20	10< d ≤20	10< d ≤15
C	20< d ≤35	20< d ≤35	15< d ≤25
D	35< d ≤55	35< d ≤50	25< d ≤35
E	55< d ≤80	50< d ≤70	35< d ≤50
F	80< d	70< d	50< d

The third intersection (general administration of commercial bank) and its coordinates (570160.45 E, 3625352.13 N): Designated as intersection No. 3, it connects the city's center to Al-Naseem Street, the highway road to the north, Omar Al-Mukhtar Street and the industrial district to the south, the new Al-Bayda neighborhood, Al-Ahad market and the city's eastern entrance to the east and Al-Orouba street to the west.

Fourth intersection (Al Wahda Bank) and its coordinates (570920.21 E, 3625552.00 N): Designated as intersection No. 4, it connects Omar Al-Mukhtar Street to the south, Al-Orouba street to the east and west and the eastern campus of Omar Al-Mukhtar University to the north.

Materials and Methods

The study's objectives are to utilize sidra software version 5.1 in order to analyze the existing traffic performance of the selected intersections; inspect several traffic alternatives and select the best option.

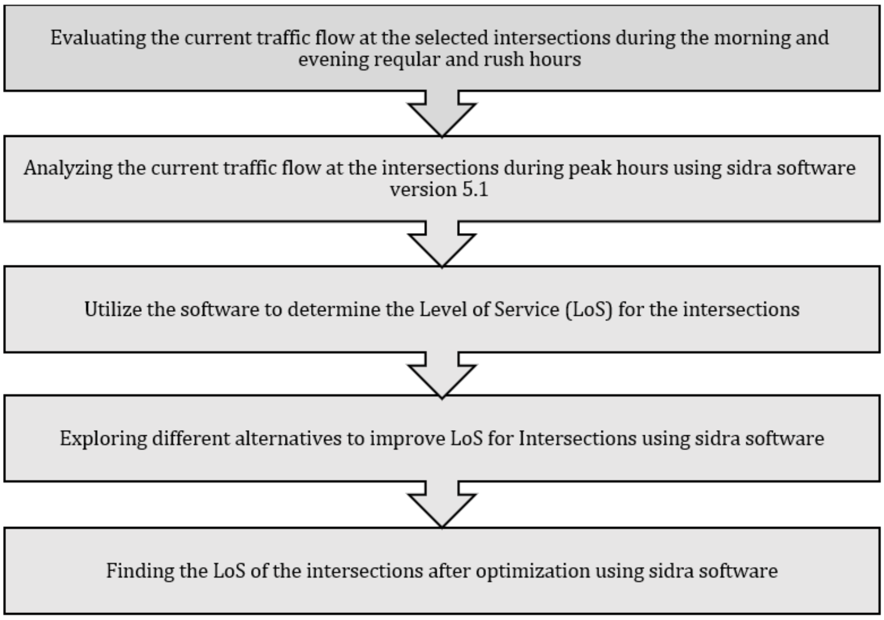

Fig. 1: The steps required to analyze the intersections

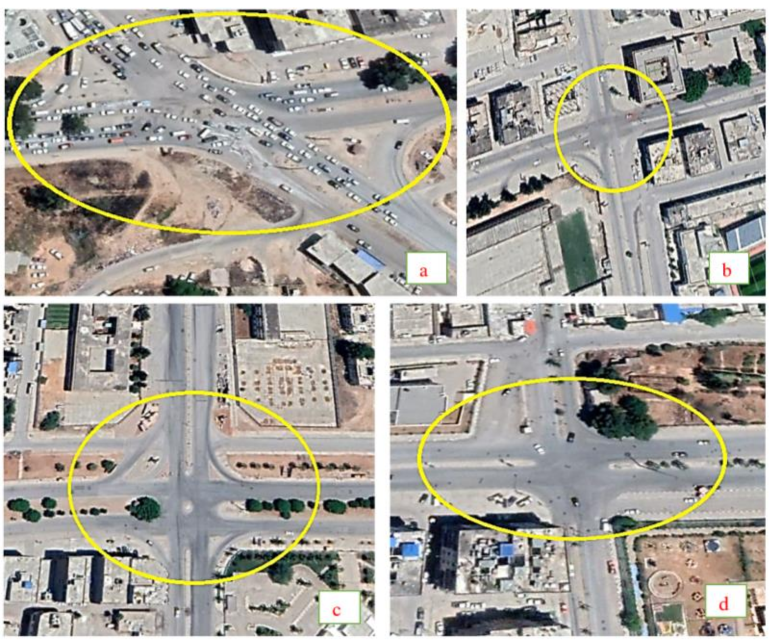

Fig. 2: The four legs intersections: (a) intersection no. 1, (b) intersection no. 2, (c) intersection no. 3, (d) intersection no. 4

The methodology of this study was divided into four main steps: Data collection, data analysis by software sidra 5.1, optimization, and selecting the appropriate option to improve traffic flow at the intersections. Figure 1 depict the research methodology and procedures followed herein.

Following a field survey for the selected intersections, the volume of traffic flow was estimated during typical working days from Saturday to Thursday, 8 h per day, every 15 min. Surveillance cameras were also used for monitoring the traffic flow at the intersections and google images were used for additional data collection. Peak times were seen to be between 12:30 and 1:30 in the morning and between 5:30 and 6:30 in the evening.

Results and Discussion

It was observed that the peak hours ranged from 12:30 to 1:30 PM and 5:30-6:30 PM.

The results obtained from the software after entering the necessary data revealed that the level of service at selected intersections was low during peak hours in the morning and evening. The LoS ranged between F and D, which indicates that there were issues at the studied intersections, necessitating the development of solutions in an effort to raise the level of service and thus increase traffic flow rate, reduce delay time, and increase driver’s comfort. The results of LoS at different intersections for morning and evening hours summarized in Table 2.

In order to improve LoS of the four intersections, several options were examined with the aid of sidra software and can be summarized as following:

1. Adjusting the time of the traffic signal for the cycle time of the intersection according to the traffic volume of the intersection
2. Increasing the shoulders of the road inside the intersection
3. Increasing the intersection's capacity by adding new lanes

Figures 3-4 demonstrate the outputs of the software for intersection No. 2 for the morning period before and after the improvement. After making the proposed modifications previously mentioned, the results before and after the optimization are summarized in Tables 3-4.

Table 2: Demonstrates the intersections' LoS in the morning and evening

Intersection no.	LoS (PM)	LoS (AM)
1	E	F
2	D	E
3	D	F
4	E	F

Table 3: The results of the Level of Service (LoS) and delay time during the morning period

Intersection no.	LoS before improvement	LoS after improvement	Delay time before improvement (sec)	Delay time after improvement (sec)	Delay time improvement (%)
1	F	C	85.3	37.2	43.6
2	E	C	70.2	31.1	44.3
3	F	B	81.4	26.3	32.3
4	F	C	84.7	35.6	42.0

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: Ind st.											
1	L	285	0.0	0.857	77.5	LOS E	26.3	183.8	1.00	0.94	19.3
2	T	213	0.0	0.857	63.5	LOS E	27.2	190.3	1.00	0.94	20.5
3	R	215	0.0	0.857	69.6	LOS E	27.2	190.3	1.00	0.95	20.9
Approach		713	0.0	0.857	70.9	LOS E	27.2	190.3	1.00	0.94	20.1
East: Auroba ST.											
4	L	241	0.0	0.825	73.2	LOS E	25.2	176.4	1.00	0.92	20.1
5	T	245	0.0	0.825	60.0	LOS E	25.8	180.9	1.00	0.92	21.2
6	R	226	0.0	0.825	64.6	LOS E	25.8	180.9	1.00	0.92	21.9
Approach		712	0.0	0.825	65.9	LOS E	25.8	180.9	1.00	0.92	21.0
North: FACILITY											
7	L	207	0.0	0.859	79.7	LOS E	24.2	169.6	1.00	0.95	19.0
8	T	215	0.0	0.859	66.9	LOS E	26.3	183.8	1.00	0.95	19.9
9	R	247	0.0	0.859	70.7	LOS E	26.3	183.8	1.00	0.94	20.6
Approach		669	0.0	0.859	72.3	LOS E	26.3	183.8	1.00	0.95	19.8
West: UN ST											
10	L	316	0.0	0.860	77.9	LOS E	26.4	184.6	1.00	0.94	19.1
11	T	187	0.0	0.860	62.9	LOS E	27.3	191.1	1.00	0.95	20.7
12	R	210	0.0	0.860	70.0	LOS E	27.3	191.1	1.00	0.95	20.8
Approach		713	0.0	0.860	71.7	LOS E	27.3	191.1	1.00	0.94	20.0
All Vehicles		2807	0.0	0.860	70.2	LOS E	27.3	191.1	1.00	0.94	20.2

Level of service (LoS) method: Delay (Manual, 2000)
Vehicle movement LoS values are based on average delay per movement
Intersection and approach LoS values are based on average delay for all vehical movement

Fig. 3: The results of the Level of Service (LoS) and delay time for intersection no. 2 at the morning period before the improvement

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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: Ind st.											
1	L	285	0.0	0.900	51.6	LOS D	12.2	85.2	1.00	1.11	24.9
2	T	213	0.0	0.641	30.8	LOS C	7.2	50.2	0.98	0.83	30.9
3	R	215	0.0	0.140	8.8	LOS A	0.7	5.2	0.21	0.70	48.0
Approach		713	0.0	0.900	32.5	LOS C	12.2	85.2	0.75	0.90	31.2
East: Auroba ST.											
4	L	241	0.0	0.830	45.4	LOS D	9.3	65.0	1.00	0.99	26.8
5	T	245	0.0	0.804	35.9	LOS D	9.2	64.1	1.00	0.96	28.8
6	R	226	0.0	0.148	8.8	LOS A	0.8	5.6	0.21	0.70	48.0
Approach		712	0.0	0.830	30.5	LOS C	9.3	65.0	0.75	0.89	32.0
North: FACILITY											
7	L	207	0.0	0.871	49.6	LOS D	8.4	58.7	1.00	1.05	25.5
8	T	215	0.0	0.862	40.6	LOS D	8.6	60.0	1.00	1.03	27.1
9	R	247	0.0	0.161	8.8	LOS A	0.9	6.3	0.21	0.70	48.0
Approach		669	0.0	0.871	31.7	LOS C	8.6	60.0	0.71	0.92	31.5
West: UN ST											
10	L	316	0.0	0.855	45.4	LOS D	12.5	87.3	1.00	1.01	26.8
11	T	187	0.0	0.482	27.6	LOS C	5.9	41.0	0.93	0.76	32.4
12	R	210	0.0	0.137	8.8	LOS A	0.7	5.1	0.20	0.70	48.0
Approach		713	0.0	0.855	30.0	LOS C	12.5	87.3	0.75	0.86	32.5
All Vehicles		2807	0.0	0.900	31.1	LOS C	12.5	87.3	0.74	0.89	31.8

Level of Service (LoS) method: Delay (Manual, 2000)
Vehicle movement LoS values are based on average delay per movement
Intersection and approach LoS values are based on average delay for all vehical movement
Sidra standard delay model used

Fig. 4: The results of the Level of Service (LoS) and delay time for intersection No. 2 at the morning period after the improvement

Table 4: The results of the Level of Service (LoS) and delay time during the evening period

Intersection no.	LoS before improvement	LoS after improvement	Delay time before improvement (sec)	Delay time after improvement (sec)	Delay time improvement (%)
1	E	C	74.6	34.2	45.8
2	D	B	42.4	29.5	69.5
3	D	B	52.3	30.1	57.5
4	E	C	78.6	38.3	52.0

The level of service increased for intersections and ranged between B and C during the peak hours for the two periods after the proposed improvements by adjusting the timing of the traffic signal cycle, which was found to be the major factor in reducing traffic congestion at the intersections.

Conclusion

The current study aimed to evaluate the performance of four main intersections in Al-Bayda city, Libya, by means of sidra 5.1 software. The LoS was used as the primary factor in this study, with LoS indicating traffic flow rate at intersections and across the entire road network.

The study concluded that, one of the most crucial methods for increasing the effectiveness of traffic flow at intersections was changing the timing of the traffic signals.

It was found that, by navigating different alternatives to improve the current situation at the selected intersections, the Level of Service (LoS) after the improvement during the morning period ranges between (C, B) and the percentage of the reduction of the delay time ranges between 30.3 and 44.3% and the level of service in the evening period ranges between (C, B) and the reduction of the delay time ranges from 45.8-69.5%.

The reduction in delay time would improve the traffic flow rate, increase speed and reduce travel time, thus reducing fuel consumption and CO_2 emissions. Additionally, it was noted that certain intersections need routine maintenance (repairing parts of the road and maintaining traffic signals).

In some cases, adding a new lane to an intersection is not always possible, improving traffic signal coordination and timing were regarded as the most important strategies for reducing delay time and increasing traffic flow. On the other hand, because it had an effect on lowering the volume of traffic at intersections, public transportation should be promoted and used more frequently.

Further work needs to be done in order to study the traffic flow at the intersections after applying the suggested improvements.

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Author's Contributions

Walid Ahmida and Abdullatif Mohamed: Performed laboratory experiments and conducted data analyzed of the research. Also, participated in written the manuscript.

Ashraf Fadiel and Taher Abu-Lebdeh: Provided the research topic and guided the research development, experimental plan, and data analyzed. Also, participated in written the manuscript.

Ethics

The authors would to disclose that Dr. Taher Abu-Lebdeh (Co-author) is a member of the editorial board for the American journal of engineering and applied sciences.

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