Research Article

Rasha Hassan Al-Rubaee* and Irfan Talib Hameed

Performance analysis, evaluation, and improvement of selected unsignalized intersection using SIDRA software – Case study

https://doi.org/10.1515/eng-2022-0537
received June 29, 2023; accepted September 19, 2023

Abstract: Significant social, economic, and environmental costs are associated with traffic congestion. The effectiveness of intersections makes a substantial contribution to the effectiveness of entire road networks. The three-leg at-grade Al-Husainea intersection, located 20 km from the center of holy Karbala city in Iraq, is subjected to serious congestion, resulting in an increase in delay time, reduction in capacity, and bad level of service (LOS). Therefore, it is essential to use advanced software tools to ensure that the current intersection can be controlled, evaluated, and improved. So, the major goal of this study is to use SIDRA, an acronym for signalized and unsignalized intersection design and research aid, software to evaluate the LOS of the Al-Husainea intersection, in which the traffic is assessed using the current LOS. LOS, delay time, and degree of saturation were the criteria utilized to evaluate the traffic flow performance. SIDRA is also used to assess benefits as a result of suggested changes in the design of particular junctions. The first stage is to gather field data regarding traffic volumes utilizing a method of traffic volume gathering. From 7 am to 6 pm, the SIDRA program gathered data for a full 7 days. The results showed that the LOS for the Al-Husainea intersection in the Al-Husainea arm is F, with an average delay of 52 s per vehicle and a saturation level of 0.86 v/c. Finally, it was determined that the Al-Husainea intersection needs additional improvements based on the study and findings from the SIDRA program, and some remedies are suggested in this study to improve the intersection traffic flow.

*** Corresponding author: Rasha Hassan Al-Rubaee,** Civil Engineering Department, University of Technology - Iraq, Alsinaa Street 52, 10066 Baghdad, Iraq, e-mail: 40323@uotechnology.edu.iq
Irfan Talib Hameed: Holy Karbala Road and Bridge Directorate, Road and Bridge Department, Ministry of Construction, Housing, and Municipality, Karbala, Iraq, e-mail: irfance84@gmail.com

Keywords: SIDRA intersection, unsignalized intersection, traffic congestion, level of service, delay time, traffic volume

1 Introduction

In Iraq, roads make up a substantial portion of the transportation network and are crucial to economic development. The enormous growth in Iraq's population has raised the demand for goods and services across the board [1]. The rapid and unplanned increase in the number of vehicles in Iraq cities had caused many problems, including traffic congestion, a high rate of delay, and a poor level of service (LOS), because the current road network was designed in a period when the population was less, which in turn is linked to a limited number of vehicles where the road network can accommodate these vehicles. The carrying capacity of the roads in the cities has become disproportionate to this increase in the number of vehicles, which has negatively affected the traffic flow [2].

According to their level of complexity, intersections can be divided into two categories: simple intersections, where two roads intersect at a right angle, and complex intersections, which accommodate three or more crossing roads in the same space [3]. The comfort of drivers and passengers on any street or highway on road networks is impacted by the operational conditions of intersections [4,5].

Congestion has resulted from the number of vehicles' impact on traffic efficiency. However, in addition to bottlenecks, intersections are one of the main sources of traffic congestion [6]. Congestion due to high volumes of traffic is a major problem in urban areas. Congestion increases the travel time delay and has a significant economic and environmental impact [7].

Over the last decade, the number of vehicles has affected traffic performance, causing congestion. However, intersections, where different flows intersect, are among the primary causes of traffic congestion besides bottlenecks [6].

For the intersections to be improved, maintaining a sufficient degree of traffic operation and safety is of utmost importance. Additionally, if the LOS decreases, there will be more traffic jams, accidents, fuel usage, emitted pollutants, and noise. According to the World Health Organization, bad traffic and congestion reduce people's quality of life, use energy inefficiently, and contribute to global warming [8–10].

The operation and effectiveness of the transportation network may be impacted by a poorly performing unsignalized intersection. Due to the priority of traffic on the main road, unsignalized crossroads represent possible hazards that are not present in signalized crossings [11]. The effectiveness of traffic intersections is governed by the volume of traffic there overall. To increase the capacity of crossings, particularly in metropolitan areas, traffic engineers must therefore pay close attention to the research of crossing [12,13].

Therefore, improving these crossings' performance has a significant impact on how well highways operate as a whole. As a result, one of the most efficient strategies to shorten delays at crossings is to increase traffic flow. Hasan and Hussein [14] and Al-Marafi et al. [15] also found that poor traffic management and parking problems were two of the most typical causes of delays at city intersections.

According to Akçelik [16], a roundabout's and intersection's capacity is the primary factor influencing how well they function. For instance, FHWA [17] outlines three essential performance indicators for assessing a roundabout's performance: the level of delay, queue length, and saturation. As an additional performance indicator, the degree of service is also highlighted [18,16,17].

The average total vehicle delay of all movements through an intersection is known as the intersection LOS [19]. According to previous studies [18,20], it is frequently described as a combination of speed, journey duration, interruptions, comfort, or convenience. According to previous studies [19,21], vehicle delay assesses intangible variables such as lost travel time and drivers' discomfort and annoyance. As measures of an intersection's potential capacity and performance, delay and LOS are important contributing factors for moderate traffic congestion [22]. According to Joni and Hikmatt [9], additional performance metrics include the spatial volume of queues, the number of vehicle pauses at meetings, and vehicle delay. Each facility has a defined procedure and a performance metric that may be calculated for assessing capacity and LOS. These performance measures are influenced by the operational circumstances of each facility, including the traffic, roadway, and control circumstances [14]. The LOS for unsignalized junctions is determined by the computed or measured control delay defined for each minor movement [19].

Due to the excessive delay, the intersection may have numerous issues. As a result, impatient drivers may act irrationally and dangerously on the road [23,24].

Poor road network design tactics usually result in delays and lengthen travel times during normal and peak hours, which in turn contribute to traffic congestion at intersections [25]. Due to modern technological advancements, many engineers and designers working in the fields of transportation, urban planning, and traffic systems are now using computer simulation. This allows the designer to test a variety of solutions and operational conditions and look for the best solutions and alternatives [26].

The amount of time it would take a vehicle to pass through an intersection without any barriers is used to calculate the delay of a vehicle there [27]. The LOS is calculated using the average total delay of all vehicle movements through the intersection (LOS) [28].

SIDRA, an acronym for signalized and unsignalized intersection design and research aid, was created by the Australian Road Research Council (ARRB) [25]. According to Al-Omari and Ta'amneh [29], SIDRA is a popular microanalytical software used in traffic engineering for a lane-by-lane examination of various intersection types with timing, amplitude, performance, and signal analysis for isolated intersections. Delay, optimal cycle duration, saturation level, LOS, performance index, fuel consumption, pollutants, and operational expenses are some of the output outcomes from SIDRA software [30]. SIDRA software is the finest software tool for forecasting field delay durations at crossings, according to [31].

This article aims to evaluate and analyze the existing traffic flow of the most important and congested intersection in holy Karbala city using SIDRA software. In addition, this article attempts to propose potential solutions to the existing problem in the presented intersection.

This study can aid the transportation system designers in estimating the LOS and delay time and anticipating future transport volumes and congestion, which allows them to explore a wide range of solutions and search for the best economic solution and alternative to solve the existing and future congestion problem and enhance the traffic flow along the intersection.

2 Materials and methods

This study is applied to the Al-Husainea intersection, located 20 km from the center of holy Karbala city as

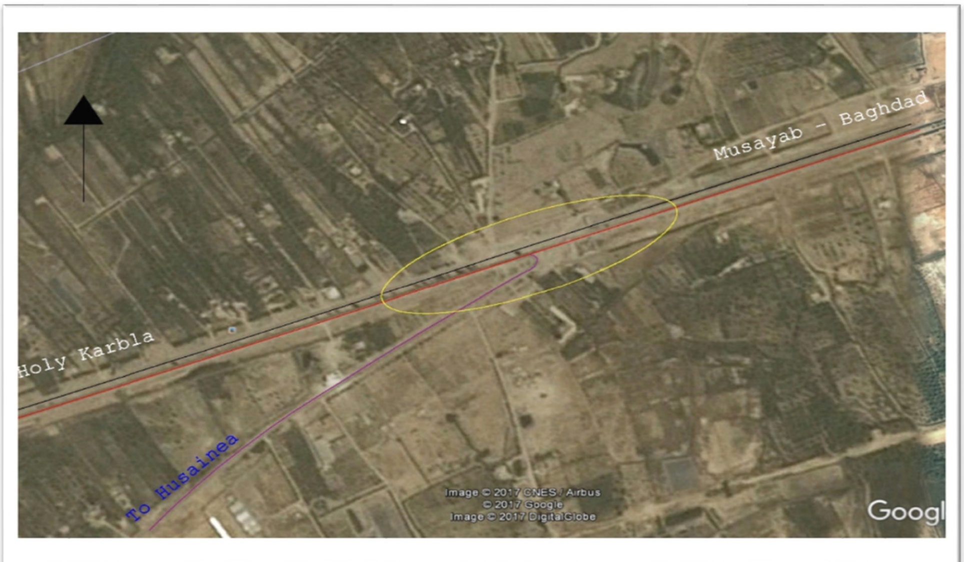

Figure 1: Location of the studied intersection.

illustrated in Figure 1 with coordinate (424604 E 3619783 N) Northeast of the holy city of Karbala. It is a three-leg intersection where Karbala-Baghdad road forms two legs of that intersection, which is a two-way two-lane on each side (7 m for each side) with 10 m median (3 m shoulder with 8% slope outside) and a third leg formed by Al-Husainea branch road which is two-way one lane which intersects with 15°, and the layout of the intersection is illustrated in Figure 2 and its terrain is level.

The study is carried out in the following steps:

1. Identification of the congested study area.
2. Data collection: Data for the intersection of all movements in each approach and their classification (passenger vehicles, trucks, and buses) were manually gathered. Every 15 min during 12 h, on weekdays and weekends from 7:00 am to 7:00 pm, data were collected.
3. Data analysis and evaluation: Microsoft Excel was used to analyze the measured traffic data in order to establish the peak hour flow, which was then utilized to assess the performance of the chosen intersection using SIDRA software.
4. Performance improvement: Exploring different potential suggestions to improve the intersection LOS.

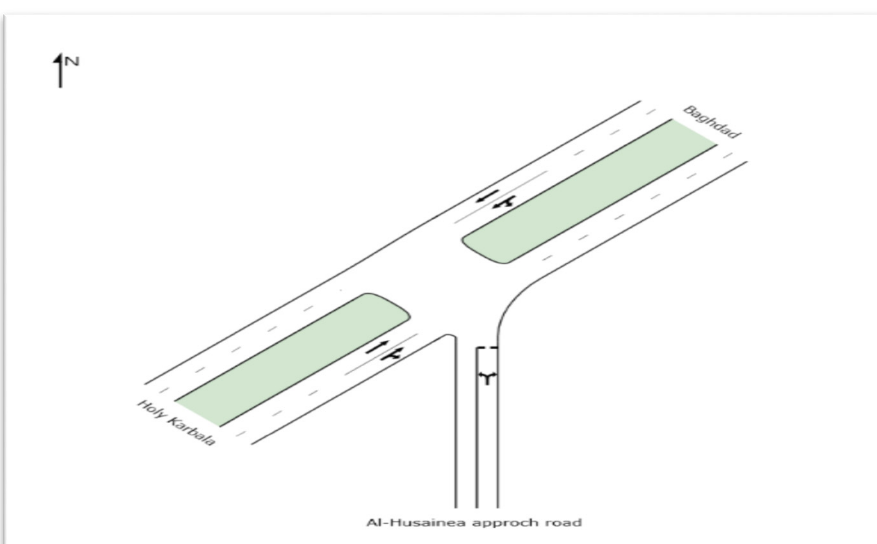

Figure 2: The intersection layout.

3 Results and discussion

Many kinds of vehicles are broken down into three categories: buses, trucks, and passenger automobiles. It is simpler to identify the types of cars that commonly use the road when they are divided into a few classes, especially during rush hours [32]. Thus, it is possible to examine the kinds of cars that are frequently seen at the Al-Husainea crossroads. The mix of the vehicles at the intersection under study is shown in Figure 3.

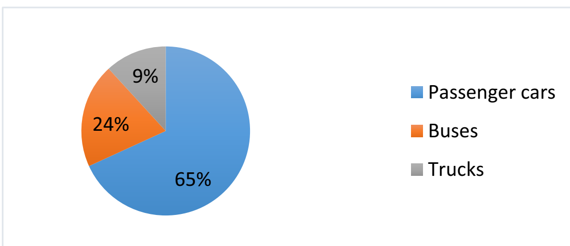

Figure 3: Vehicle composition.

For Musayab Arm (Musayab-Karbala) in the selected intersection, it is noted that traffic volumes were 529, 614, and 535 pcu/h on Wednesday, Thursday, and Friday, which are the highest, as many visitors are coming to the holy shrine on Karbala (AL-Imam AL-Husain and AL-Imam AL-Abbas), so all visitors from the capital and the cities north Holy Kabala used this way (Musayab-Karbala), as presented in Figure 4.

While for the opposite direction (Karbala-Musayab), the highest value of traffic volumes was 758 pcu/h on Sunday, which is the first day of working days, and most of the students go to their universities in Baghdad, and the people who have businesses in offices and ministries prefer to go at the beginning of the week (Figure 5).

Similarly, for Karbala Arm (Karbala-Musayab), the highest value traffic volumes were on Sunday, the first day of working days. Most students go to their universities in Baghdad, and the people who work in offices and ministries and others prefer to go at the beginning of the week. However, for the opposite direction (Musayab-Karbala), it was noted that the traffic volumes were 485, 490, and

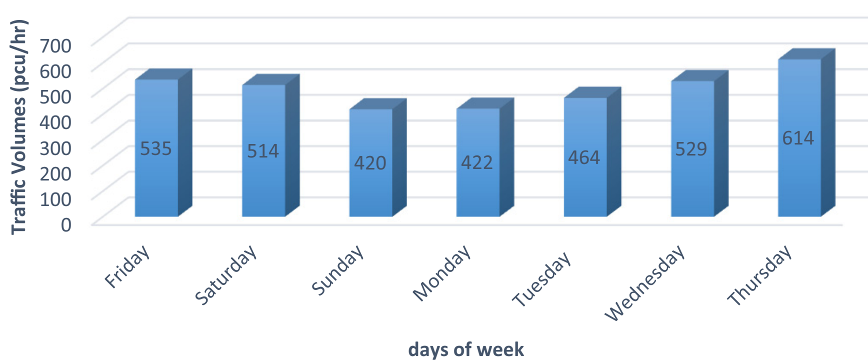

Figure 4: Total traffic volume at Musayab Arm (Musayab-Karbala).

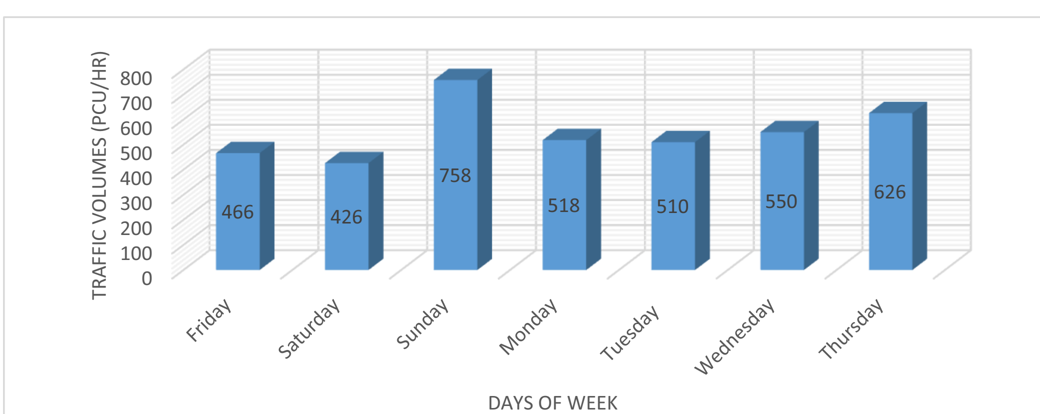

Figure 5: Total traffic volume at Musayab Arm (Karbala-Musayab).

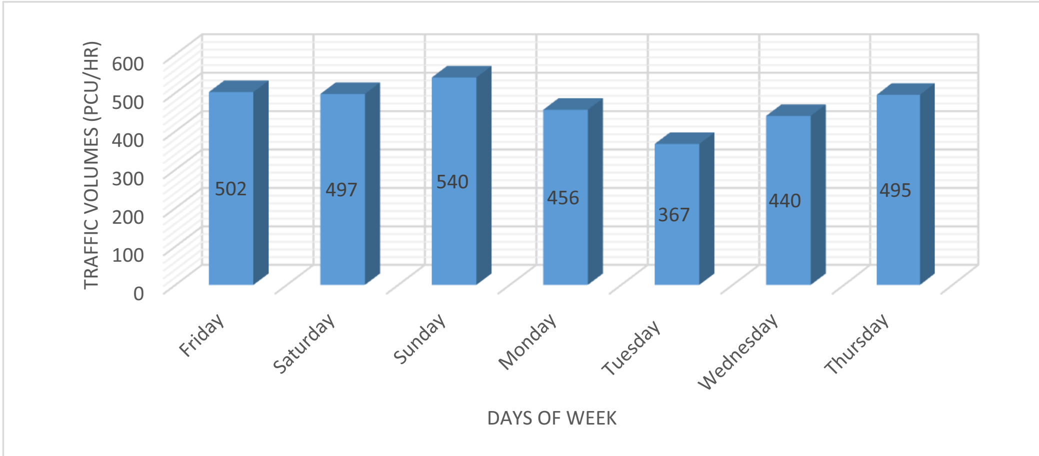

Figure 6: Total traffic volume at Karbala Arm (Karbala-Musayab).

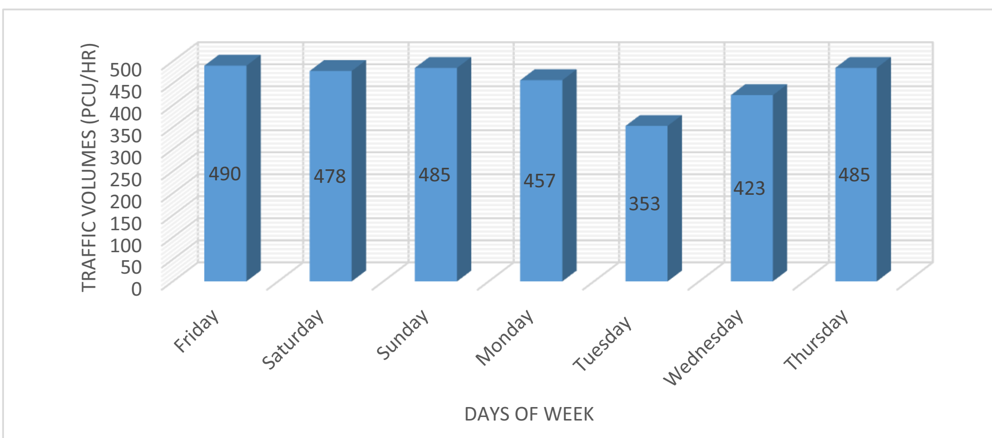

Figure 7: Total traffic volume at Karbala Arm (Musayab-Karbala).

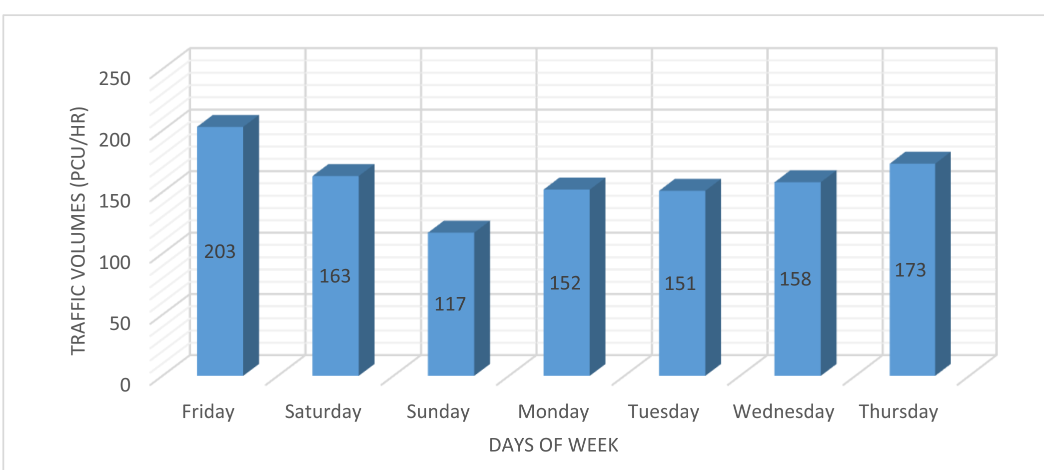

Figure 8: Total traffic volume at Husainea Arm (Musayab-Husainea).

478 pcu/h on Wednesday, Thursday, and Friday, which are the highest, as many visitors are coming to the holy shrine in Karbala (AL-Imam AL-Husain and AL-Imam AL-Abbas), so all visitors from the capital and the cities north Holy Kabala used this way, as illustrated in Figures 6 and 7.

Figure 8 shows that the highest values of traffic volumes for Husainea Arm (Musayab-Husainea) were 173, 203, and 163 pcu/h on Thursday, Friday, and Saturday. Sometimes when there is high traffic on the main road on the mentioned days or because of the checkpoints, some drivers

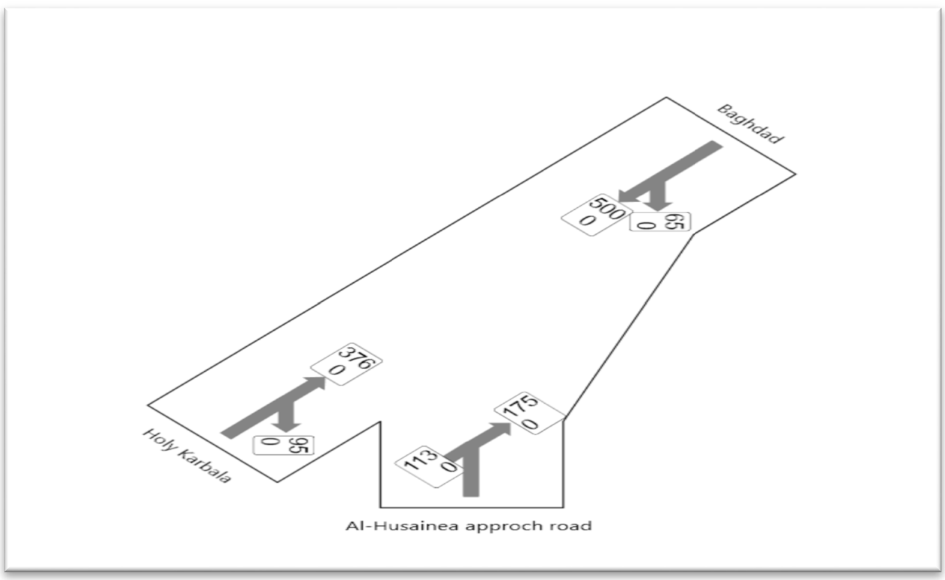

Figure 9: The intersection volume.

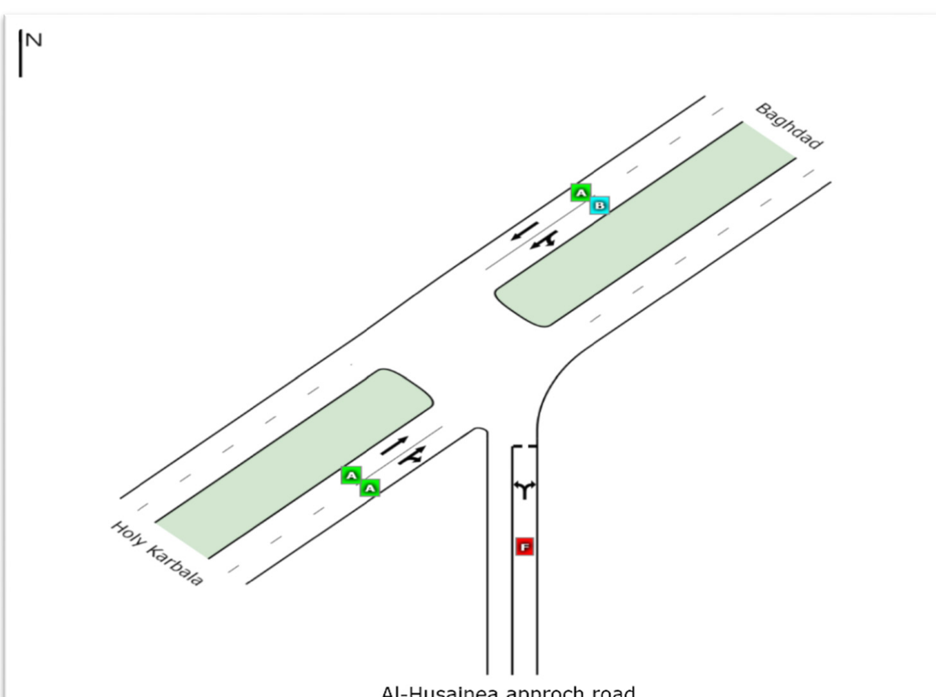

Figure 10: LOS of Al-Husainea intersection.

prefer to use the AL-Husainea branch to reach holy Karbala city.

As mentioned earlier, the SIDRA intersection program was used to analyze the data which were collected at the site, which needs the dimension for each lane, the number of lanes in each approach, and the median width if it exists, then the volume for all movements, as illustrated in Figure 9.

The corresponding LOS can be obtained after assigning the traffic volumes for each arm in the intersection, as illustrated in Figure 10. The results for the LOS were as follows: all movements in Karbala–Baghdad way were with LOS A; all movements at Husainea road were of LOS F; and the movement at Baghdad–Karbala way was with LOS A and LOS B as illustrated in Figure 11. Figures 12 and 13 present the average delay and the degree of saturation.

Based on the obtained results, the LOS for the Musayab-Karbala and Karbala-Musayab arms is excellent, which are LOS A and LOS B. In contrast, for Husainea's component, the LOS is very poor LOS F, which causes inconvenience and discomfort to road users. In addition, the degree of saturation for Husainea's arm is exceptionally high, resulting in a high density of vehicles and high congestion. Additionally, the average delay in this arm is 53.1 s, which means that the car will be in line for a longer period of time.

With the aid of SIDRA software, a number of recommendations for enhancing the LOS for the Husainea arm were tested. They can be summed up as follows:

1. Changing the geometric layout of the Karbala–Musayab road as illustrated in Figure 13 showed no change in LOS

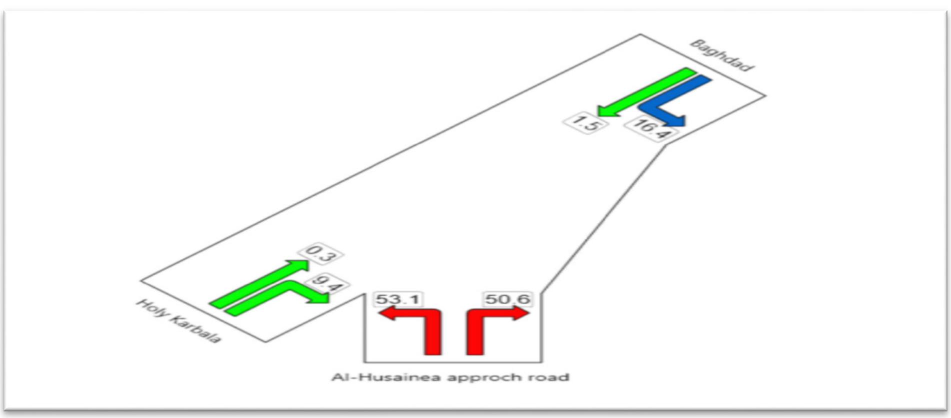

Figure 11: The average delay in the intersection.

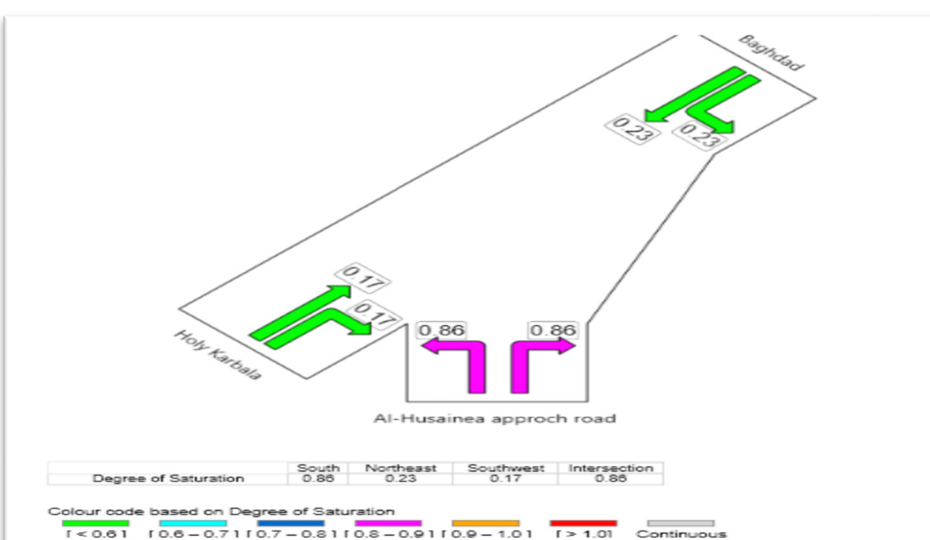

Figure 12: Degree of saturation for Al-Husainea intersection.

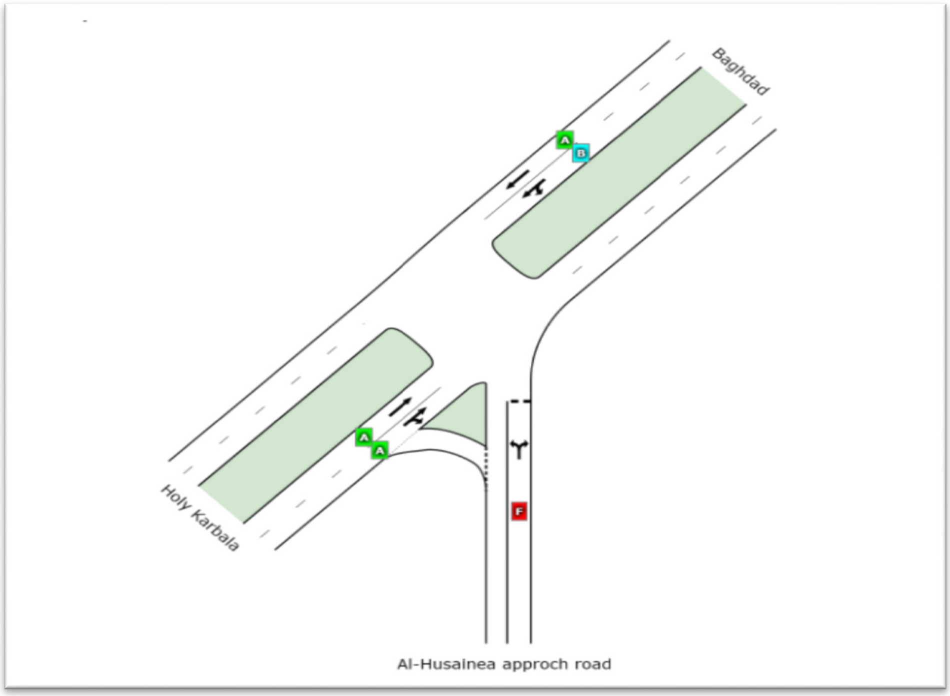

Figure 13: Changing the geometric design in the Karbala arm.

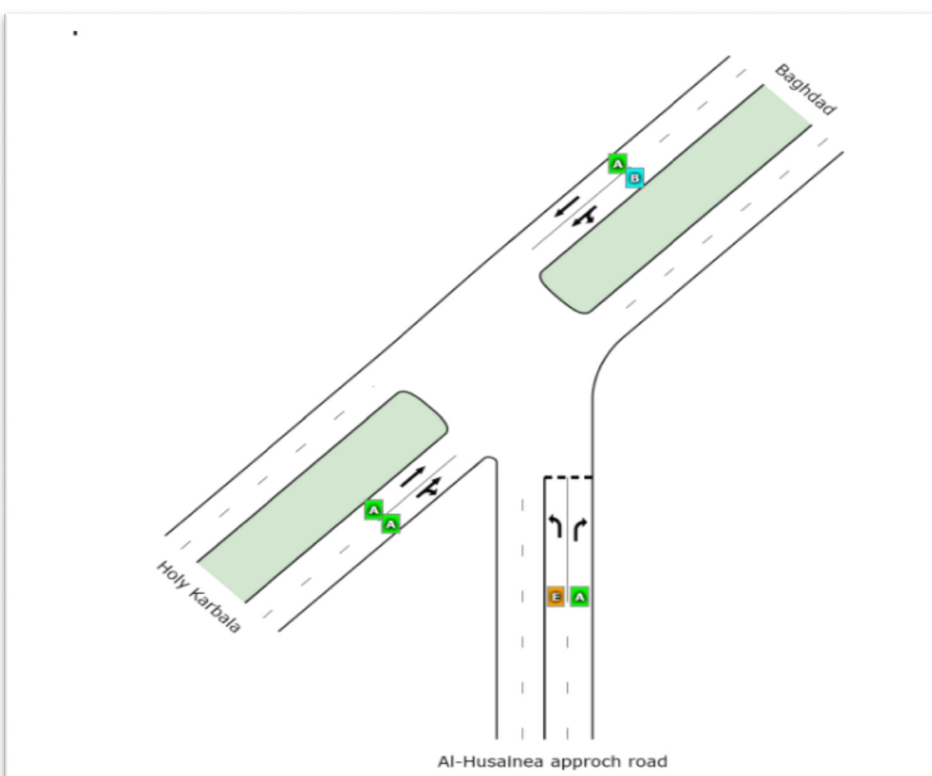

Figure 14: Increasing the capacity of AL-Husainea approach road.

F in the AL-Husainea approach road so it cannot be used as it is not useful.
2. Signals (cycle time) are re-coordinated based on the volume of traffic. This leads to an LOS E, which cannot be very efficient according to the current traffic conditions.
3. Increasing the capacity of the Al-Husainea approach road by adding new lanes and then using SIDRA to find the new LOS A and E, which can be accepted as presented in Figure 14. This improvement is more economical than the others and gives a good result, which can be used to make all approaches have a satisfied LOS.
4. It is possible that an overpass can be used on the AL-Husainea branch road to avoid conflict with other traffic, which can result in an excellent LOS, but what is taken on this option is that it is too expensive compared with different options.

4 Conclusions

This study has been conducted at the AL-Husainea intersection in Karbala, Iraq, for analysis, evaluation, and improvement, and SIDRA software has a valuable practical application for the studied intersection. After adopting the SIDRA software, it was concluded that currently the LOS in the AL-Husainea approach road is F, which is a really bad LOS due to high delay, while the other LOS is between A and B.

In Musayab-Karbala road, the traffic volumes are highest on Thursday, Friday, and Saturday, while for Karbala–Musayab road, the results revealed that the highest traffic volume is at the beginning of the week (Sunday). On the other hand, the Al-Husainea approach road has a high volume of traffic on visit days of the week (Thursday, Friday, and Saturday). It works in times of high congestion as an assistant to the Musayab-Karbala road for visitors to the holy city of Karbala. The road, which only has two lanes – one in each direction – has a low capacity, which is the cause of the congestion.

In order to solve the congestion and the bad LOS problem, four suggestions have been presented in this study to improve the LOS for the Husainea arm, among which, the one with increased capacity and the one with the overpass are the best.

The obtained findings can help local authorities monitor the performance of the current intersection so intervention can be done to control the congestion.

Nevertheless, further work should be done to study the intersection traffic flow after the suggested improvement. It is suggested to analyze and evaluate the other intersections in Karbala City using the same approach in order to build a database regarding the existing LOS in the city. Other software tools, such as VISSIM and SYNCHRO, may be applied to the current intersection for the results comparison.

Funding information: Also, I declare that the manuscript was done depending on the personal effort of the author, and there is no funding effort from any side or organization.

Conflict of interest: The authors state no conflict of interest.

Data availability statement: Most datasets generated and analyzed in this study are in this submitted manuscript. The other datasets are available on reasonable request from the corresponding author with the attached information.

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