Emerging Trends in Engineering and Sustainability (ETES) Volume 02 (No. 03), 2026, pp. 25-38

Emerging Trends in Engineering and Sustainability (ETES)

https://etes.alnaji-uni.edu.iq

https://doi.org/10.65505/ETES-26-0010

ISSN 3105-1723 (Print)
ISSN 3105-1731 (Online)

Improvement Proposals of Al-Kansaa Intersection

Miami M. Hilal[1*], Sarab Mehdy[2], Nahla M Salim[3]

[1] Highway and Geotechnical Department, Civil Engineering College, University of Technology-Iraq, Baghdad, Iraq.
[2] The State Corporation for Roads and Bridges, Baghdad, Iraq.
[3] Civil Engineering Department, College of Engineering, Al-Naji University, Baghdad, Iraq.

Article Info

Received: 10 June 2026
Revised: 29 June 2026
Accepted: 03 July 2026
Available online: 30 September 2026

Keywords:

Intersections;
Traffic volumes;
Level of service;
Civil 3D geometric design program;
HCS 2010.

ABSTRACT

Intersections are among the most critical elements of highway networks because they directly influence traffic efficiency, capacity, and safety. This study evaluates improvement alternatives for Al-Kansaa's three-leg intersection in Iraq, which currently experiences severe traffic congestion and operates at Level of Service (LOS) F. Traffic volume surveys and geometric data were collected and analyzed using Highway Capacity Software (HCS2010), while Autodesk Civil 3D was employed to develop and evaluate four geometric improvement alternatives. The existing intersection analysis indicated an average control delay of 398.66 s/veh, corresponding to LOS F. The first improvement proposal, which involved adding a lane to the southbound approach, reduced the average delay to 165.67 s/veh; however, the intersection continued to operate at LOS F, indicating that geometric widening alone was insufficient. Therefore, three grade-separated interchange alternatives were developed and assessed based on operational performance, geometric feasibility, land-acquisition requirements, and constructability. Among the proposed alternatives, the interchange incorporating two bridges and a roundabout was identified as the most suitable solution because it provides smoother traffic operations, minimizes land acquisition, reduces construction constraints, and preserves the operational performance of the major roadway. The findings demonstrate that comprehensive geometric redesign is more effective than minor geometric modifications for improving heavily congested three-leg intersections and may serve as a practical reference for similar intersections in developing countries. The novelty of this study lies in the integrated evaluation of four alternative intersection improvement proposals by combining traffic operational performance, geometric design, constructability, and land-acquisition considerations within a single decision framework for a real-world three-leg intersection.

1. Introduction

Intersections are one of the most critical and complicated elements in highway design. Intersections are planned points of conflict where two or more roadways join or cross, and they control the efficiency, capacity, and safety for motorized and non-motorized users of the facility. The type and operation of an intersection is important to the adjacent property owners, motorists, bicyclists, pedestrians, transit operators, the trucking industry, and the local community [1].

© 2026 The Author(s). Production and hosting by Al-Naji University.
This is an open access article under the CC BY 4.0 license https://creativecommons.org/licenses/by/4.0/

Al-Khansaa is a 3–leg intersection linking Al-Nahrowan and Diyala. It has a vital role in the local region. It suffers from high congestion and delay, so it needs restoration in order to enhance its performance. Design suggestions for improvements of Al- Khansaa intersection were developed to improve the safety and capacity of the congested intersection because as stated in the AASHTO 2011, the main objective of intersection design is to: "reduce the severity of potential conflicts between motor vehicles, buses, trucks, bicycles, pedestrians, and facilities, while facilitating the convenience, ease, and comfort of people traversing the intersections." [2].

Many researchers have adopted the performance improvement of intersections and analysed the results by using design software programs. For example, Al-Ekaby in 2001 selected the Antar Square intersection, which is part of the Adhamiyah network and located at a congested city center in Baghdad [3]. Al-Ekaby used the Highway Capacity Software HCS program to analyse the intersection data and minimize the intersection delay, and used TRANSYT-7F to test the traffic performance of the intersection and to evaluate and improve the traffic flow patterns of the network. The Iraqi State Corporation for Roads and Bridges suggested enhancing a four-leg intersection on the road of Baghdad-Kut by converting it to a full clover leaf in order to connect the road of Baghdad-Umara with the road Kut-Badra. The intersection was designed with AutoCAD Civil 3D and Land Desktop Companion 2009; the design was completed in 2011. [4]

Another example is Al-Swaira Intersection, which is located on the Baghdad-Kut road. The Iraqi State Corporation for Road and Bridges suggested adding a lane and an overpass road that connects the Al-Swaira road. It has been designed using the Civil 3D program [4]. Improvements suggested by the Iraqi State Corporation for Road and Bridges on the Somer intersection, which is located at Expressway section No.5 (Baghdad-Basra), to connect Daghra with Somer townships in Al-Diwaniyah governorate. The design was done by the AutoCAD Civil 3D Land Desktop Companion 2009 design program; the design was completed in 2012 [4].

Al-Haydari (2011) evaluated the performance of seven selected intersections located in arterials at the holy city of Karbala; three of them were four-leg signalized intersections, and the remaining four were roundabouts. SYNCHRO software was used in the evaluation and analysis of signalized intersections, and SIDRA intersection software was used in the evaluation and analysis of both signalized intersections and roundabouts. She suggested some improvement proposals which vary from changing the timing plan, geometric improvements, to changing the intersection type completely [5]. Al-Hamzawi (2012) assessed and evaluated traffic performance for the Mohammed Al-Qasim Expressway in Baghdad City by using the Highway Capacity Software HCS 2000 program, which elicited the LOS of basic segments and weaving area sections. Artificial Neural Network ANN and regression models were used to develop the speed and density models of the traffic stream using SPSS 19 [6].

The geometric design of the intersections plays a critical role in managing traffic flow and minimizing congestion [7]. The intricate network of road types and their contributory role in traffic accidents has garnered significant attention in the realm of civil engineering [8].

Ali and Al-Hadad (2025) [9] evaluate traffic conditions on the Kasnazan arterial road (known as Erbil-Koya Road) using field data and VISSIM microsimulation. The analysis focused on peak-hour traffic, geometric road design, and Level of Service (LOS) metrics. Four improvement scenarios were simulated: lane expansion, ramp implementation, driver behavior adjustments, and access point optimization.

Results demonstrated that lane expansion and ramp installations significantly enhanced traffic flow, reducing delays by up to 93% and lowering CO emissions by 63%, while improving LOS to D or C. Driver behavior modifications and access point management also yielded moderate improvements.

Unlike previous studies that evaluated isolated operational improvements, this study integrates operational performance analysis, geometric design, constructability considerations, and land-acquisition constraints into a comprehensive decision framework for selecting the most appropriate interchange configuration for a heavily congested three-leg rural intersection in Iraq. Furthermore, the study presents a real

engineering case that can serve as a practical reference for similar intersections in developing countries. Al-Khansaa intersection, suggestions for improvements will be analysed using Highway Capacity Software and the 3D Civil Geometric Design Program 2014 in order to enhance its performance.

2. Research Aims

The main aims of this research are:

1. Collecting and analyzing the data of the Al-Kansaa intersection.
2. Suggesting many solutions to the intersection and selecting the most appropriate one to enhance the capacity and level of service, and reduce the delay.

3. Description of the Al–Khansaa Intersection Location

Al–Khansaa intersection is located in the area linking Al-Nahrowan and Diyala, as shown in Figure 1.

Figure 1. Location of Al-Khansaa Intersection.

4. Intersection geometric design features

Al-Khansaa intersection consists of three legs. The first leg consists of two lanes with a 10-meter median from Al-Nahrawan City (Road No.3), meets the second leg, which consists of two lanes from Canaan roadway (Road No.1), and the third leg is directed toward Baghdad (Road No.2), as shown in Figure 2 from the Google Earth application.

Figure 2. An Aerial View Shows the Intersection Area.

5. Data collection

Traffic data were collected manually by a trained survey team from the State Corporation for Roads and Bridges. The survey was conducted simultaneously at three observation stations, as presented in Figure 2, to capture all traffic movements entering and leaving the intersection. Traffic counts were recorded continuously for 12 hours per day (7:00 a.m.–7:00 p.m.) over seven consecutive days. Each hour was divided into four 15-minute intervals to identify peak-hour traffic characteristics and calculate the Peak Hour Factor (PHF).

Vehicles were classified into passenger cars and heavy vehicles (trucks), and the percentage of heavy vehicles was determined for each approach to support the capacity analysis. To ensure data quality, standardized traffic-count forms approved by the State Corporation for Roads and Bridges were used, all survey personnel received prior instructions on the counting procedure, and the completed survey sheets were checked daily for completeness and consistency before being entered into the analysis.

collected traffic-count sheets were reviewed for completeness and consistency before data entry. The percentage of heavy vehicles was calculated for each approach and incorporated into the operational analysis. The processed traffic data were then used as input to Highway Capacity Software (HCS 2010) for estimating capacity, control delay, and Level of Service (LOS).

Table 1. Maximum traffic volumes for the three approaches.

Road No.	Day and Date	Total Volume Baghdad (veh/day)	% of Truck
Road No.1	Wednesday (3/6/2015)	21738	42
Road No.2	Friday 5/6/2015	13100	43
Road No.3	Friday 5/6/2015	12162	41

Table 1 shows that the traffic volume on the road (Canaan-Baghdad) (Road No.1) is higher than the road (Nahrawan-Baghdad) (Road No.3) and the road directed toward Baghdad (Road No.2).

5.1 Road No.1 Canaan–Baghdad Road

The peak hour was from 7 AM to 8 AM on Wednesday 3 / 6/ 2015 in the morning. The peak hour is divided into quarters in order to calculate the peak hour factor (PHF) as shown in Table 2.

Table 2. The data on the peak hour of Road No.1

Time (am)	7:00-7:15	7:15- 7:30	7:30- 7:45	7:45-8:00	Total	PHF
Peak Traffic Volume (veh/h)	700	778	680	642	2800	0.9

5.2 Road No.3 Nahrawan – Baghdad Road.

Friday 5 / 6/ 2015 was the highest traffic volume and the peak hour from 7 am in the morning to 8 am, in the morning as shown in Table 3.

Table 3. Peak hour data of Road No.3.

Time (am)	7:00-7:15	7:15- 7:30	7:30- 7:45	7:45-8:0	Total	PHF
Peak Traffic Volume (veh/h)	370	423	400	294	1487	0.88

5.3 Road No.2 is directed to Baghdad.

Friday 5 / 6/ 2015 was the highest traffic volume, and the peak hour was from 10 am in the morning to 11 am, in the morning as shown in Table 4.

Table 4. Peak hour data of Road No.2.

Time (am)	10:00-10:15	10:15- 10.30	10:30- 10:45	10:45-11:00	Total	PHF
Peak Traffic Volume (veh/h)	400	425	390	370	1585	0.93

6. Data analysis of the intersection

Analysis and assessment of the capacity, level of service, and delay for the unsignalized intersection were done using the Highway Capacity Software HCS-2010 program. Capacity, Level of service, and delay results are presented in Table 5, where the level of service was (F) for the whole intersection.

Table 5. Highway Capacity Software Analysis Results (Capacity, LOS, and Delay).

Properties	Eastbound EB		Westbound WB		Northbound NB		Southbound SB	
	L1	L2	L1	L2	L1	L2	L1	L2
Flow Rate veh/sec.			372	375	393	400	1400	
Service Time sec.			5.3	4.5	5.5	5.3	5.0	
Utilization, x			0.75	0.67	0.86	0.85	2.73	
Dep. Headway, hd			7.28	6.46	7.84	7.63	7.03	
Capacity veh./sec.			494	557	459	472	1400	
Delay sec./veh			29.24	21.74	41.88	40.02	800.40	
LOS			D	C	E	E	F	
Approach								
Delay sec./veh			25.47		40.94		800.40	
LOS			D		E		F	
Intersection Delay: 398.66 sec./veh					Intersection LOS: F			

7. Proposals and Solutions for Improvements

The geometric design of each proposed alternative was developed in accordance with the design recommendations of AASHTO (2004) and the Iraqi Highway Design Manual. All alternatives were evaluated using identical traffic demand, geometric design standards, and operational assumptions to ensure a consistent comparison. The preferred alternative was selected based on several engineering criteria, including operational performance (capacity, delay, and Level of Service), geometric feasibility, construction complexity, land-acquisition requirements, environmental considerations, and overall implementation feasibility. These criteria were used to compare the proposed alternatives systematically through the decision matrix presented in the revised manuscript.

7.1 Proposal No.1

The level of service for the whole intersection was (F), which is required to enhance the intersection by adding additional lanes for approaches. The SB approach should be improved by adding a lane because the delay of this approach was the greatest (800.4 sec./veh.). The HCS 2010 program was used in the analysis of the new geometric feature suggested for the intersection. The results show that the delay of the SB approach was reduced to 301.72 sec/veh. But the level of service for the intersection is still (F), as shown in Table 6, and it is required to suggest another solution in order to enhance the performance of the intersection.

Table 6. Highway Capacity Software Analysis Results (Capacity, LOS, and Delay).

Property	Eastbound EB		Westbound WB		Northbound NB		Southbound SB	
	L1	L2	L1	L2	L1	L2	L1	L2
Flow Rate veh/sec.			372	375	393	400	800	600
Service Time sec.			5.2	4.4	6.3	6.1	6.0	5.4
Utilization, x			0.75	0.67	0.94	0.93	1.84	1.28
Dep. Headway, hd			7.23	6.42	8.58	8.37	8.27	7.65
Capacity veh./sec.			498	561	420	430	800	600
Delay sec./veh			28.66	21.40	59.83	56.68	405.63	163.16
LOS			D	C	F	F	F	F
Approach								
Delay sec./veh			25.01		58.24		301.72	
LOS			D		F		F	
Intersection Delay: 165.67 sec./veh					Intersection LOS: F			

7.1.1 HDM Procedure to Select Another Solution for the Intersection:

To decide how to select a suggested solution for the intersection, the following procedure is proposed by the Iraqi Highway Design Manual [10]:

The type of intersection will be decided according to the Iraqi Highway Design Manual for the State Corporation for Roads and Bridges. Figure 3 shows a relationship between the PCU 24 hr on the main road and the PCU 24 hr on the minor road.

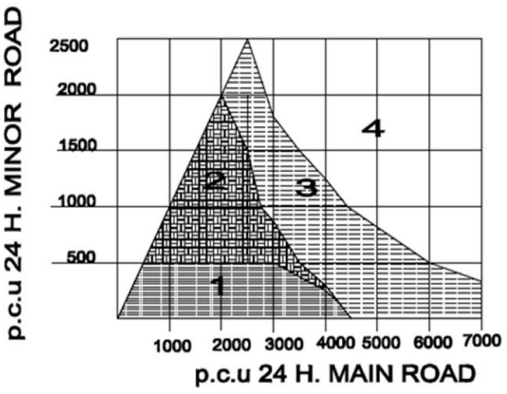


Figure 3. Selection of the type of intersection based on traffic volume [10].

The numbers in Figure 3 refer to the following:

1. Intersection without traffic islands.
2. Divisional and channelizing triangular islands on the minor road.
3. Divisional and channelizing triangular islands on the minor road and a divisional island on the main road.
4. Control the intersection or interchange.

Traffic volume at the Al-Kansaa intersection was projected in the previous figure. The major road was road No.1, and the minor road was road No.3. The analysis of the average daily traffic (ADT) for roads is:

$$ADT = (\text{total weekly traffic} / 7 \text{ days}) \ldots (1)$$

Where:

PCU = passenger car unit.

FH = The weighting for each class of vehicle has to be varied to suit the purpose for which they are to be used.

$$ADT\ (PCU/day) = (ADT*(100 - (\%of\ truck))) + (\%of\ truck* FH* ADT) \ldots (2)$$

Table 7. Factors of the weight for the class of vehicle [10].

Passenger car/car unit	Light truck car /car unit	Medium (average) Truck /car unit	Heavy goods vehicle/car unit
1	1.25	2	3

Table 8. Volume of traffic on road no.1 (major road) and the proportion of heavy vehicles.

Total volume (vehicle/week)	% of Average Truck/week	Factor of HV (HDM)
130525	42	2

ADT = 130525/7 =18647 veh/day, say 18650 veh/ day

The number of PCU = 18650*((100-42)/100)*1 + 18650 *((42/100)*2) = 26483 say 26500 pcu/ day.

Table 9. Volume of traffic on road no.3 (minor road) and the proportion of heavy vehicles.

Total volume (vehicle/week)	% of Average Truck/week	Factor of HV (HDM)
69572	32	2

ADT = 69572/7 = 9939 veh/day, say 9950 veh/day

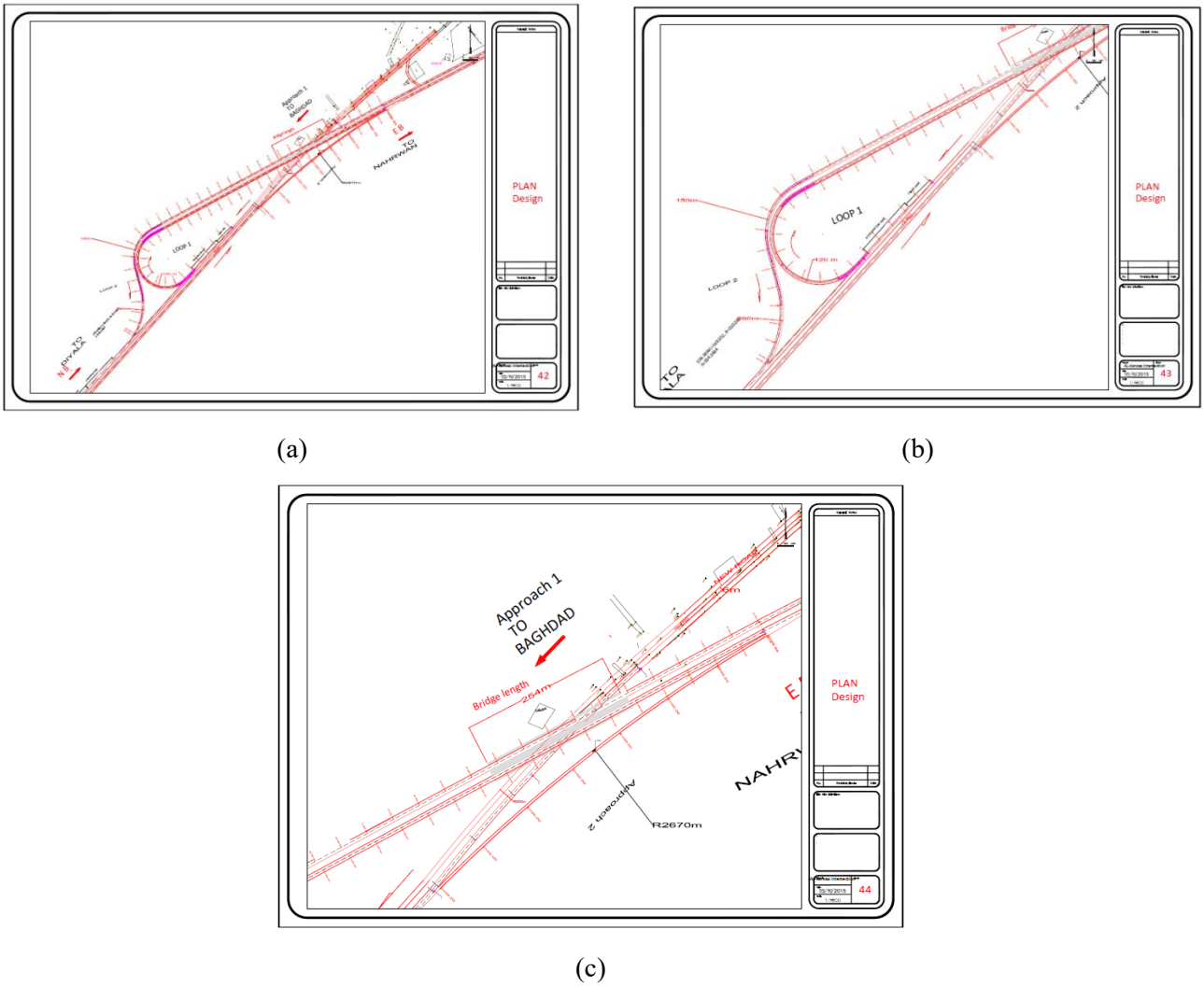
The number of PCU = 9950*((100-32)/100)*1 + 9950*((32/100)*2) = 13134 pcu/day say 13150 pcu/day

From the previous calculations, the average volumes of traffic from the major and minor roads during the day require large volumes, so the selected intersection type solution will be an interchange, according to Figure 3.

7.2 Proposal No.2

This suggestion requires connecting the SB approach with the NB approach directly by an underpass, and the WB approach will be connected to the NB approach and the SB approach by a trumpet. The Civil 3D program was used to check the design criteria of the suggested interchange according to the AASHTO 2004 specifications.

Figure 4 shows the interchange geometric design with all details of the proposal. In order to satisfy the specifications criteria, it is required to provide large areas because of the availability of skewed angles and provide long paths in order to achieve the comfort performance for the driver. On the other hand, this suggestion is expensive because the State should buy the adjacent areas as well as the construction cost, so another solution should be suggested.



(a) (b)

(c)

Figure 4. The interchange geometric design of proposal No.2.

7.3 Proposal No.3

To solve the problems of suggestion No.2, this suggestion will present an intersection with 90° angle instead of a skew angle; this will reduce the large areas required in suggestion No.2 and reduce the costs. The solution was a three-leg interchange with a single-structure trumpet. This solution requires shifting the intersection 600 m towards the SB. A team from the State Corporation for Roads and Bridges were done additional survey for the area supervised by the author using the Total Station Device. The 3D Civil program was used to design the suggested interchange.

This proposal design requires short paths to regulate the paths of the interchange approaches and a short bridge length (60 m), and this is a good technical and economic choice, but the interchange passes through the blocks of residential buildings and shops; that's not appropriate environmentally and economically because of the high costs of acquisition. It is required to suggest another solution for the interaction to enhance its performance. Figure 5 shows the geometric design of the interchange with details for each design approach.

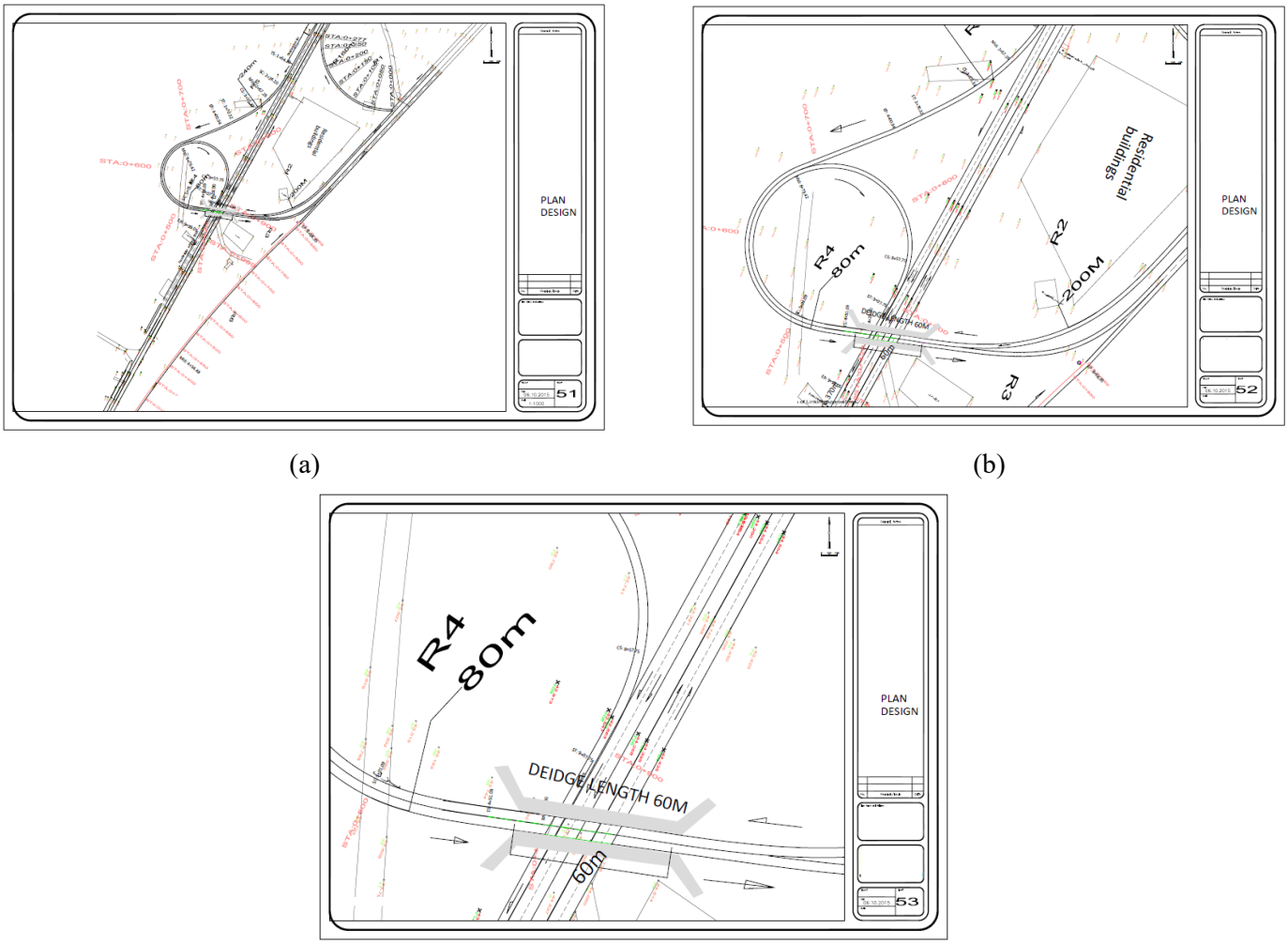


Figure 5. The Geometric Design of Proposal No. 3, shifting the intersection 600 m towards the SB.

7.4 Proposal No. 4

The angle of intersection is proposed to be 15 °. The type of the selected design interchange was an overpass with two bridges with a roundabout intersection. The major priority of the movement was for road No.1, which involved two bridges for vehicles going and returning. The roundabout intersection was proposed to connect the WB approach with the service roads of the NB approach and the SB approach.

This suggested solution provides the following:

- It does not require the provision of large areas for the purposes of linking the approaches.
- Reducing the cost of acquisition.
- It provides a great, smooth flow of traffic, and it doesn't affect the performance of the major road.

For the previous reasons, this suggestion will be adopted.

The 3D Civil Design program was used to prepare the geometric design features and drawings for the suggested interchange and verify the proposed geometric design solution.

Approach Cross Section:

Road section design of two-way two-lane with travelled way width in one direction 8.25m, class A4.

- The outer shoulder width is 1.5 m.

- The inner shoulder width is 1.5 m.

The median width is 6m (Note: the median width reduces with the size to reduce the costs of acquisition Conflicts).

Retaining walls have been created on the approaches for a distance of 450 meters north of the bond approach and 300 meters south of the bond approach to provide sufficient space to pass the service roads that connect the roundabout to the bottom of the bridge. Figure 6 shows the typical cross-section of approaches. Figure 6 presents the typical cross section of the approaches, and Figures 7 to 10 show the geometric design of the interchange with details for each design approach.

Design the inscribed circle diameter by the NCHRP report (Roundabouts: An Information Guide), use the design for a multilane roundabout, 3-lane diameter 120 m and circulatory roadway width 12 m, maximum design speed range (40–50 km/hr). Figure 11 shows the typical cross-section of a roundabout.

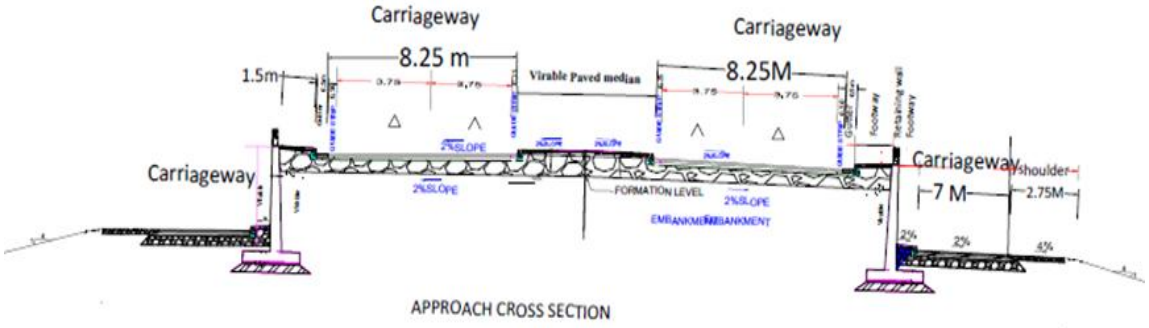


Figure 6. Typical cross-section of approaches.

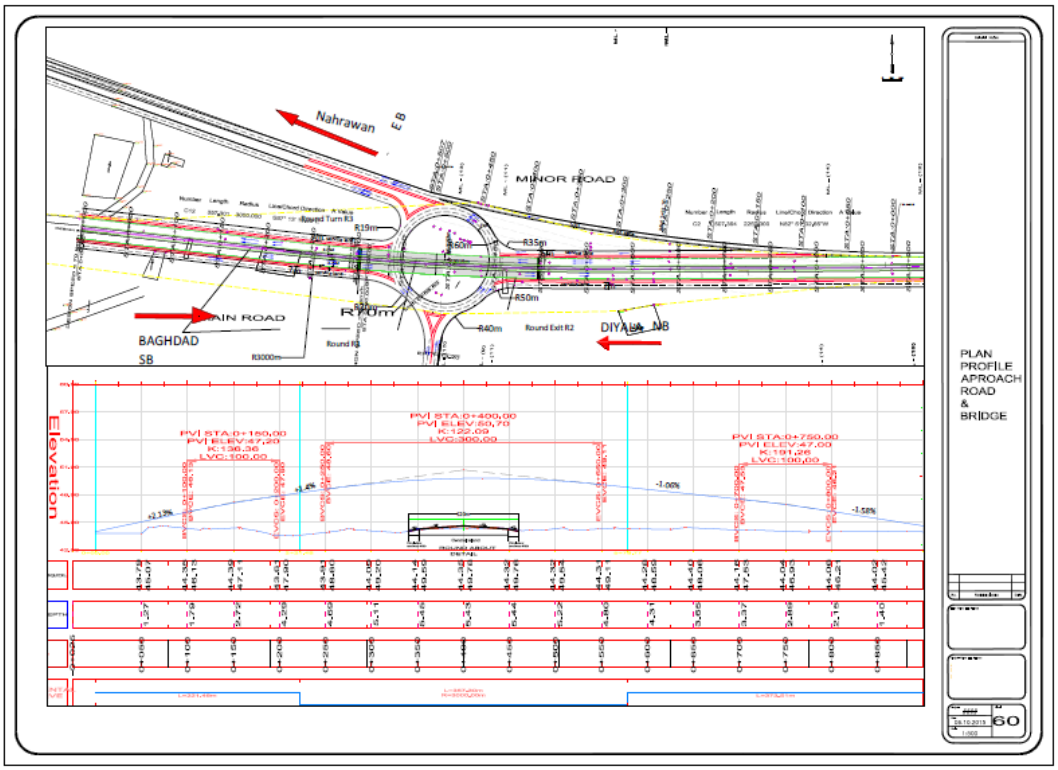


Figure 7. Geometric design of the interchange.

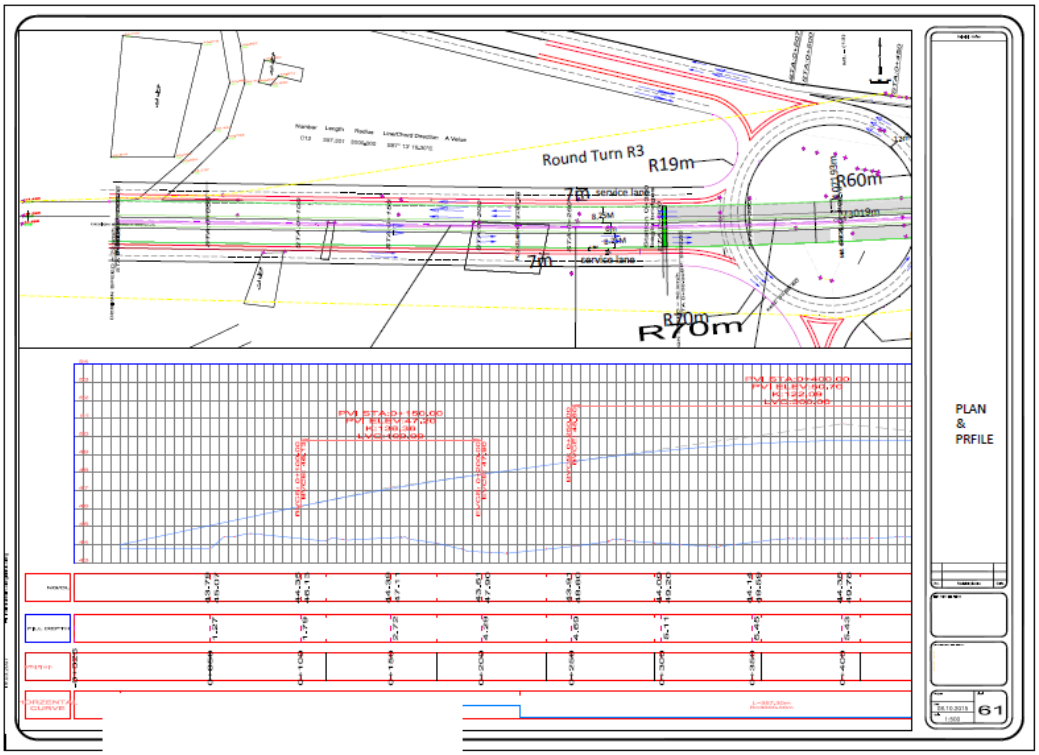


Figure 8. Geometric design of Road No.1.

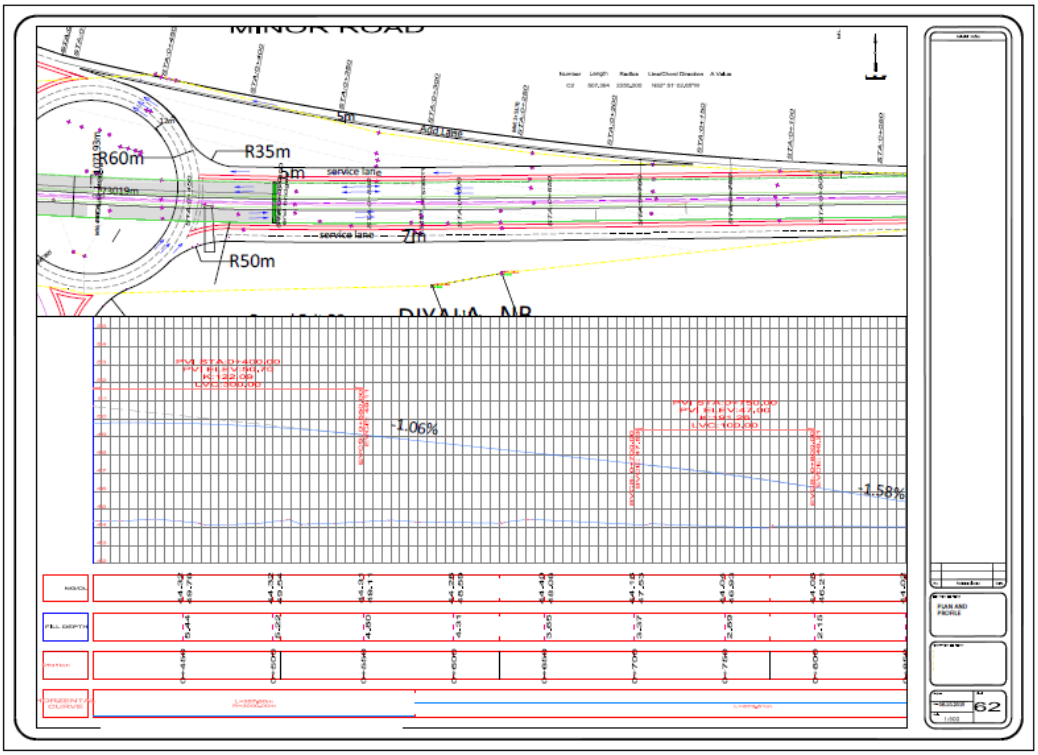


Figure 9. Geometric design of Road No.2.

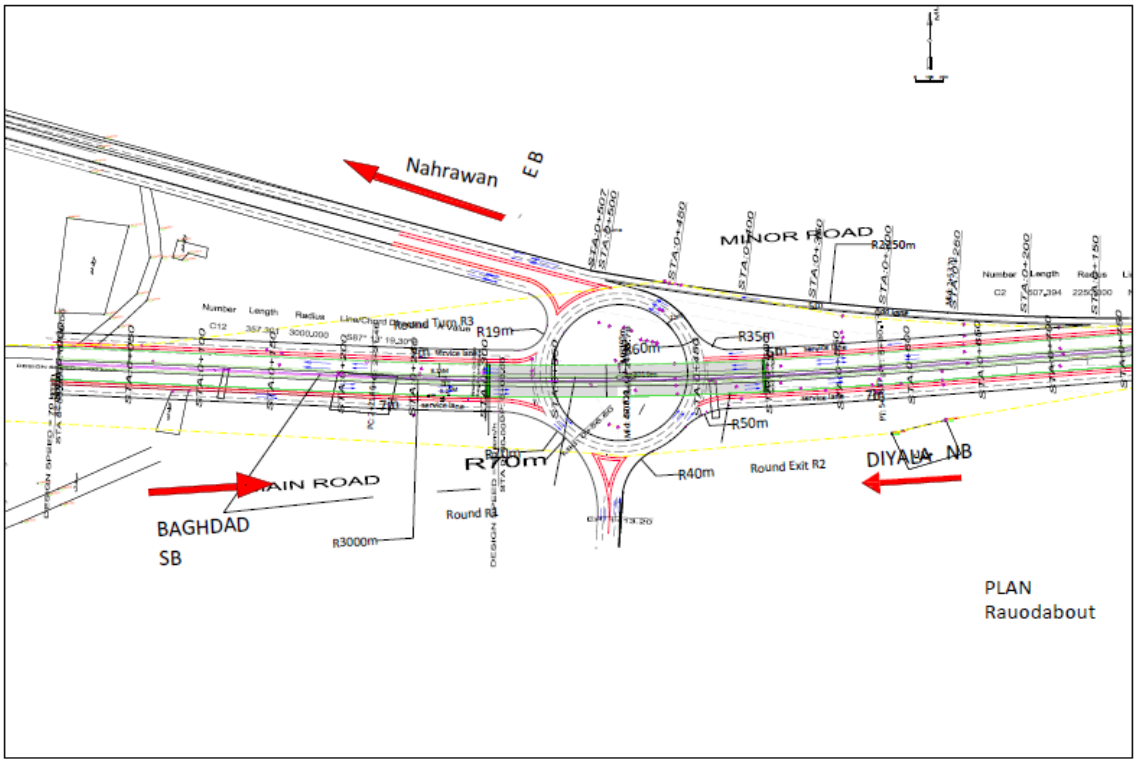


Figure 10. Geometric design of Road No.3.

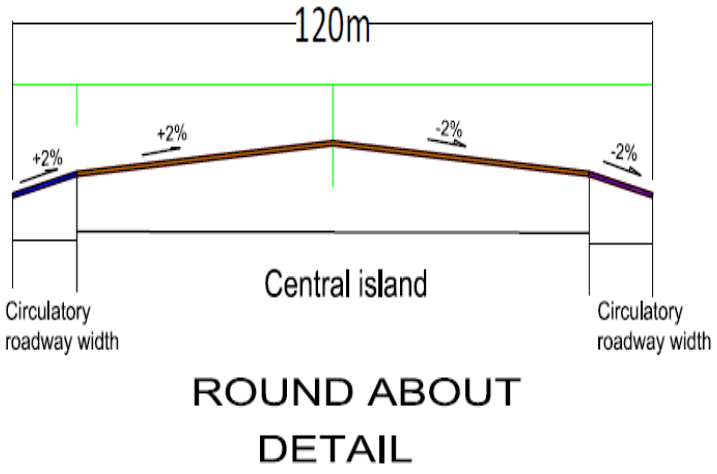


Figure 11. Typical cross-section of a roundabout.

7.5 Comparative Evaluation of the Proposed Alternatives.

To support the selection of the preferred improvement alternative, a comparative decision matrix was developed as presented in Table 10. The four proposed alternatives were evaluated using five engineering criteria that directly influence the feasibility and effectiveness of intersection improvement projects: operational performance, construction cost, land-acquisition requirements, environmental impact, and implementation feasibility. Each criterion was assigned a qualitative score ranging from 1 (least favorable) to 5 (most favorable) based on the engineering evaluation and comparative assessment presented in this study. The comparison provides a structured basis for selecting the most appropriate alternative.

Table 10. Comparative decision matrix based on the engineering evaluation presented in this study.

Evaluation Criterion	Proposal 1	Proposal 2	Proposal 3	Proposal 4
Operational performance	2	4	4	5
Construction cost	5	2	3	4
Land acquisition	5	1	2	5
Environmental impact	4	2	1	4
Implementation feasibility	5	2	3	5
Total Score	21	11	13	23

Proposal No. 4 is considered the most appropriate alternative as presented in Table 10, which has the highest score among the suggested proposals.

8. Economic Considerations

A qualitative economic assessment was conducted to support the comparison of the proposed alternatives. Proposal No. 1 represents the least expensive option because it only requires widening the southbound approach by adding a lane, with minimal construction work and negligible land acquisition. Proposal No. 2 is expected to have the highest implementation cost due to the construction of a trumpet interchange under skewed geometry, which requires extensive earthworks, longer connecting ramps, and substantial land acquisition. Proposal No. 3 reduces some geometric complexity compared with Proposal No. 2; however, its implementation would require relocation of residential buildings and commercial properties, resulting in considerable land-acquisition and compensation costs. Proposal No. 4 provides a balanced solution by minimizing additional land acquisition while improving traffic operations through grade separation and a roundabout configuration. Although its construction cost is expected to be higher than Proposal No. 1, the reduced right-of-way requirements and improved operational performance make it the most practical and economically feasible alternative among the proposed designs. A detailed cost estimate and benefit-cost analysis are recommended for future studies after completion of the final engineering design.

9. Safety Considerations of the Preferred Alternative

In addition to the operational improvements, the preferred design is expected to provide significant safety benefits. The proposed interchange separates the major through traffic from intersecting traffic movements by means of grade separation, thereby reducing the number of potential vehicle conflict points. The inclusion of a roundabout for local traffic movements also contributes to improved safety by reducing vehicle speeds at entry and exit points and eliminating high-speed crossing conflicts. Furthermore, smoother traffic flow and lower congestion are expected to reduce sudden braking, aggressive lane-changing, and driver delays, which are common factors associated with traffic crashes. Although a quantitative crash analysis was beyond the scope of this study due to the unavailability of historical accident records, the proposed design is expected to enhance overall traffic safety based on established geometric design and traffic engineering principles.

10. Discussion

The analysis demonstrates that minor geometric modifications alone are insufficient to address severe congestion at Al-Kansaa Intersection. Although Proposal No. 1 reduced the average control delay, the intersection continued to operate at Level of Service (LOS) F, indicating that adding an extra lane cannot adequately accommodate the existing traffic demand. This finding suggests that localized geometric improvements are unlikely to provide a long-term solution for heavily congested intersections with substantial through traffic.

The comparison of the four proposed alternatives showed that Proposal No. 4 provides the most balanced engineering solution. In addition to improving traffic operations through grade separation, the proposed design minimizes land-acquisition requirements, reduces construction constraints compared with the other interchange alternatives, and preserves uninterrupted traffic flow on the major roadway. These characteristics make the proposed design

more practical for implementation under existing site conditions.

From a transportation planning perspective, the findings highlight the importance of considering operational performance together with geometric feasibility, land availability, constructability, and environmental constraints during the selection of intersection improvement projects. The results demonstrate that the preferred solution should not be determined solely by traffic capacity but also by its feasibility, sustainability, and compatibility with the surrounding road network.

The proposed design may also serve as a practical reference for improving similar high-volume three-leg intersections in Iraq and other developing countries where rapid traffic growth, limited right-of-way, and budget constraints present significant challenges for transportation agencies. Furthermore, detailed economic evaluation and quantitative road safety analysis are recommended before implementation of the selected alternative.

11. Conclusions

Many proposals were suggested to enhance the performance of the Al-Kansaa intersection. The following conclusions were presented:

1. Adding a lane in the SB, as presented in the proposal No.1, did not give an improvement as the LOS still (F).
2. The construction of the trumpet intersection with a skew angle, as presented in proposal No.2, was not appropriate because of the availability of a skewed angle, and a long path should be provided in order to achieve the comfort performance for the driver to satisfy the specification criteria.
3. Implementation of the trumpet intersection with a right angle was not appropriate as presented in proposal No.3 because the interchange passes through the blocks of residential buildings and shops; that's not appropriate environmentally and economically.
4. The most appropriate suggestion was proposal No.4 because this proposal provides the following:
   - It does not require the provision of large areas for the purposes of linking the approaches.
   - Reducing the cost of acquisition.
   - It provides a great, smooth flow of traffic, and it doesn't affect the performance of the major road.

Acknowledgements

Authors can express their appreciation to the State Corporation for Roads and Bridges organization for their valuable help in collecting data and support the research with necessary information. The authors also express their appreciation to Al Naji University and University of Technology for their academic support to the research efforts.

Conflict of interest

The authors declare no conflicts of interest concerning this research.

Funding

The authors did not receive support from any organization for the submitted work.

Author Contribution

M.M. Hilal conceived of the presented idea, developed the theory and verified the analytical methods, and supervised the findings of this work. S.Mehdy carried out the experiment, wrote the manuscript and worked out almost all of the technical details. N.M. Salim verified the analytical methods, conceived the original idea and supervised the project. All authors participated in the discussion of the results and contributed to writing the manuscript.

AI Declaration Statement

The authors confirm that the manuscript has been written without the assistance of generative AI or AI-based writing tools.

References

[1] California Department of Transportation, *Highway Design Manual*, 2014.

[2] American Association of State Highway and Transportation Officials (AASHTO), *A Policy on Geometric Design of Highways*

and Streets, 6th ed. Washington, DC, USA, 2011.

[3] A. H. Al-Ekaby, "Evaluation and improvement of traffic flow patterns at Antar Square in Baghdad City," M.Sc. thesis, University of Technology, Baghdad, Iraq, Mar. 2001.

[4] *Archive of Design Plans of the Iraqi State Corporation for Roads and Bridges*.

[5] I. S. J. Al-Haydari, "Improvement of traffic flow on arterials in Holy Karbala City," M.Sc. thesis, University of Al-Mustansiriyah, Baghdad, Iraq, Jun. 2011.

[6] I. A. O. Al-Hamzawi, "Descriptive model of existing freeway in Baghdad using artificial neural network (ANN)," M.Sc. thesis, University of Al-Mustansiriyah, Baghdad, Iraq, Jul. 2012.

[7] D. Zulkarnaen, S. Mayuni, E. Mukti, and N. Nurhayati, "Geometric design of coordinated traffic signal intersections: Case study of four-way intersections at Kapuas II Bridge and Kapur Village," *J. Tek. Sipil*, vol. 24, no. 3, p. 1183, 2024. https://doi.org/10.26418/jts.v24i3.84088

[8] D. K. Hassooni, R. Ghasemlounia, M. M. Hilal, Z. H. Al-Saffar, and G. T. Mohammed, "Analyzing traffic accident trends and correlations in Iraq: An investigative statistical approach," *AIP Conf. Proc.*, vol. 3303, Art. no. 040002, 2025. https://doi.org/10.1063/5.0264564

[9] N. A. Ali and B. M. Al-Hadad, "Enhancing traffic flow efficiency towards sustainability: A case study of Kasnazan arterial road," *Eurasian J. Sci. Eng.*, vol. 11, no. 2, 2025, Art. no. 22. https://doi.org/10.23918/eajse.v11i2p22

[10] State Organization of Roads and Bridges, *Highway Design Manual*. Design and Studies Department, Road and Traffic Division, 2005.