Periodica Polytechnica Transportation Engineering

Evaluating and Improving the 14th of July Arterial Corridor

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Received: 17 December 2024, Accepted: 24 November 2025, Published online: 02 March 2026

Abstract

The 14th of July Arterial Road is one of the most important urban roads in western Baghdad, experiencing heavy traffic congestion during rush hour from 7:30 a.m. to 8:30 a.m. It has become a major traffic congestion problem. It is one of the most attractive main roads in Baghdad due to its location, extending from the north to the city center, and its connection to several major roads. In this research, three links on the 14th of July Arterial Road were selected: link 1 from Aden intersection to Sana'a intersection, link 2 from Sana'a to Tobji intersection, and link 3 from Tobji intersection to Al-Shaljiya intersection. The performance of the 14th of July Road and its intersections was analyzed using Synchro11 software under current operating conditions to study the impact of intersections on travel time on the 14th of July Arterial Road. The analysis results showed that the travel time northbound was 860.6 s with a level of service of F, and the travel time southbound was 989.9 s with a level of service of F. To improve the travel time and level of service on the main road, overpasses were proposed at the intersections. The analysis conducted after improving the intersections of 14th July Road revealed that the travel time to the northbound became 372.5 sec with service level C, and the travel time to the southbound became 249.6 sec with service level B.

Keywords

level of service, synchro, intersection

1 Introduction

The road network is the infrastructure consisting of streets and intersections, comprising points and links with specific traffic directions. It represents a fundamental element in social and economic development, as it is affected by traffic volumes and land use (Asgarpour et al., 2023). In recent years, increased traffic has led to congestion and longer travel times, forcing drivers to use alternative urban routes, increasing distances, accidents, and pollution. The level of service at intersections, especially with heavy left-hand traffic, affects the performance of the network as a whole (Hameed, 2013; Abdulwahab and Bader, 2020). Most transportation engineers agree that congestion on urban and semi-urban arterial roads is caused by congestion at major intersections with traffic lights. The delays at signalized intersections are reflected in the level of service in the city's transportation network. Researchers evaluated traffic operations at intersections using the Highway Capacity Manual 2010 (Transportation Research Board, 2010). The data include signal timing, geometric characteristics, and traffic Volume data with proposals to improve the operational performance of these intersections, including the construction of an overpass or any other policy to control The intersection movement. The software used is HCS, VISSIM, GIS, and SYNCHRO (Flaah and Ajam, 2024; Rajab, 2021; Udomsilp, 2017; Hasan and Hussein, 2022; Ziboon et al., 2019; Udomsilp et al., 2017). A study by Wang and Wu (2024) improved traffic flow at three intersections on a long road by designing a synchronized signal timing (green wave) using Synchro software. The results showed the effectiveness of the green wave system in improving traffic flow. Mohammed et al. (2024) proposed three scenarios, including changing the cycle length, restricting heavy vehicle movement, and adding lanes to improve the level of service and improve the operating conditions of the traffic signal intersection at the eastern entrance of Benghazi using Synchro software. The result analysis showed that the intersection operated at level B service when scenarios 2 and 3 were applied. A novel left-turn diversion system was put into place at continuous-flow intersections by Alkaissi (2022) in order to reduce traffic and vehicle delays. The average vehicle delay was lowered by

Cite this article as: Lateef, I. M., Abed, A. H., Asmael, N. M. (2026) "Evaluating and Improving the 14th of July Arterial Corridor", Periodica Polytechnica Transportation Engineering, https://doi.org/10.3311/PPtr.39626

almost 44% thanks to the displaced left-turn DLT. Kareem and Alkaissi (2024) evaluated and analyzed the 14th Ramadan intersection in Baghdad city using SIDRA 8.0 and SYNCHRO 11.0 programs, and made a statistical comparison of the analysis results of the two programs to confirm which program is more compatible with the intersection conditions. Building on previous studies that addressed improving the performance of urban intersections through simulation and engineering solutions, this study focuses on the 14th July arterial in Baghdad, one of the main intersections experiencing traffic delays that impact network performance. It aims to evaluate and improve the operational performance of its intersections using Synchro 11 software by implementing engineering changes, including the construction of overpasses, to increase capacity and reduce delays.

2 Methodology

2.1 Framework

A well-planned research methodology is crucial to enhancing the practical feasibility of the research findings for the intersections on 14th July Street were selected as key control points on one of the most important traffic corridors in western Baghdad, directly impacting the flow of traffic in the urban network. The morning rush hour was also selected, as this represents the period of peak traffic loads, allowing for the detection of maximum delays and travel times. This selection is consistent with the recommendations of traffic engineering manuals such as HCM and enhances the accuracy of the assessment in measuring the impact of implemented improvements. The current research utilized the study approach presented in Fig. 1

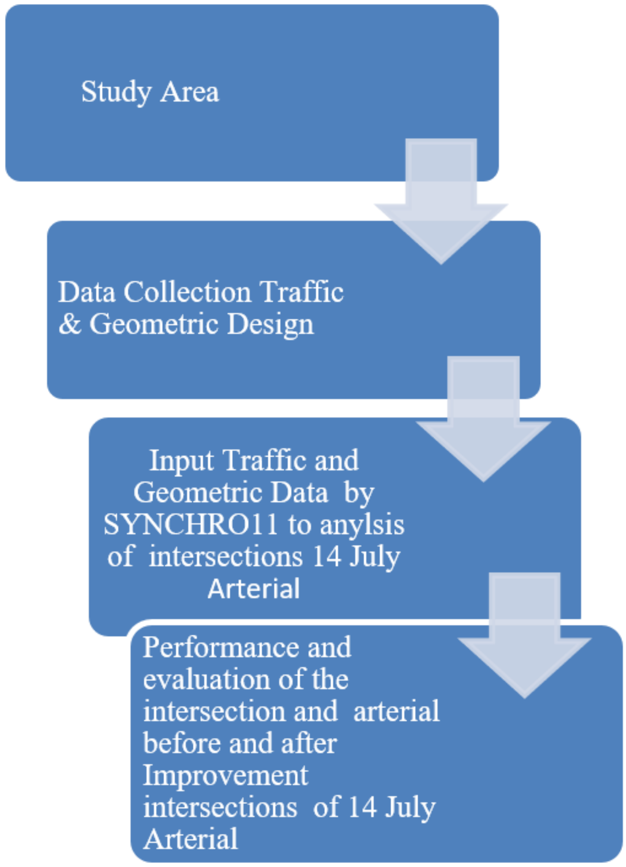


Fig. 1 Methodology of the study

2.2 Study area and data collection

2.2.1 Study area

The 14th of July Arterial is located in Karkh District, northwest of the Tigris River in Baghdad (part of Ring Road No. 1), where its northern part forms the Arterial separating the districts of Kadhimiya and Shula, and its southern part forms the Arterial separating the districts of Karkh and Mansour, as shown in Fig. 2 It is classified as a TSF according to Scott Wilson's study, as the 14th of July Arterial includes four traffic lanes in both directions with a right-of-way ranging between 70–100 m and is separated by a median. The arterial extends from its intersection with the Aden Intersection north of Baghdad to the 14th of July Bridge in central Baghdad, totaling 8.993 km. The Arterial intersects with several important major intersections. The study area includes a 3.100 km section of the

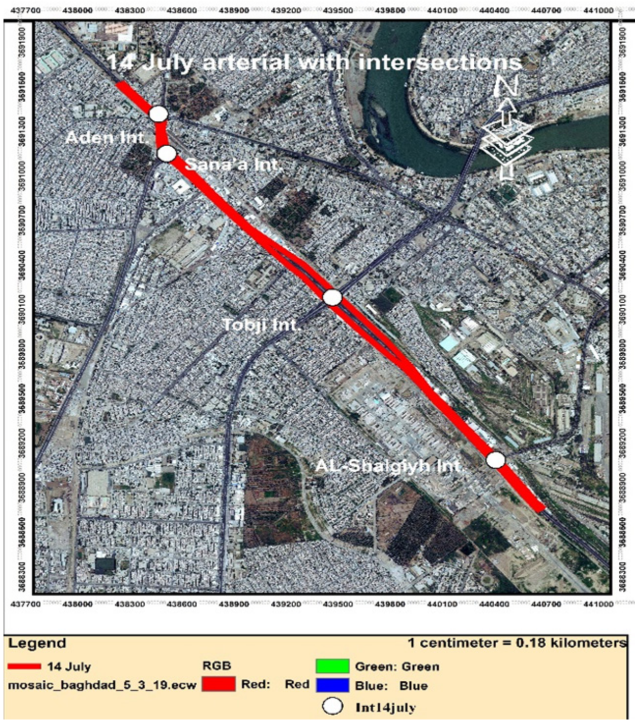


Fig. 2 Study area

above-mentioned 14th of July Arterial, which is the section bounded by the main intersections of the road, namely

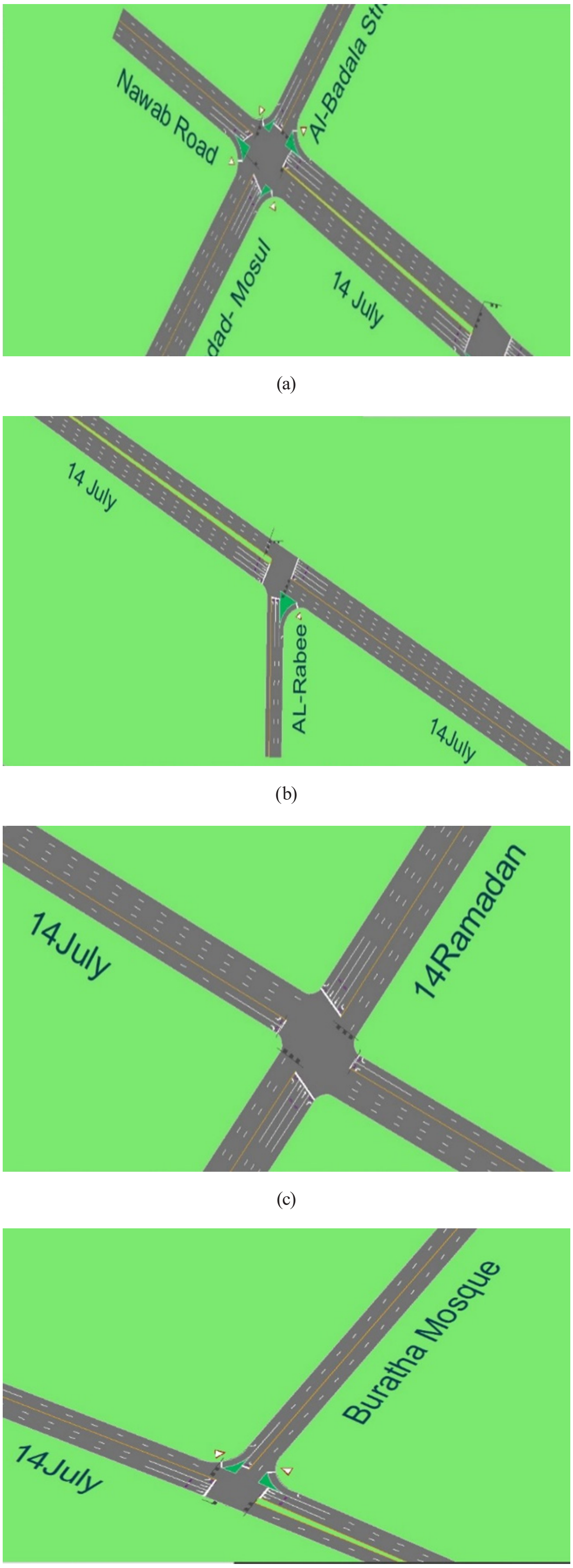
Aden Intersection, a four-way intersection classified as TSO1; Sana'a Intersection, a three-way intersection classified as TSO1; Tobji Intersection, a four-way intersection classified as TSE; and Al-Shaljiya Intersection, a three-way intersection.

2.2.2 Data collection

Traffic data and geometric characteristics of intersections on 14th July Road were collected. Field traffic counts were conducted on weekdays (Sunday, Monday, and Tuesday) from 6:30 a.m. to 5:30 p.m., and peak hours (design hour) from 7:30 a.m. to 8:30 a.m. using a combination of manual counting with camera-recorded data. Frequent field checks were performed to compare the manual count data with camera records to reduce potential errors resulting from camera angle or human fatigue during counting. Data collected included geometric characteristics (number of lanes, lane width, longitudinal slope, and speed), traffic data (volumes, PHF, HV%, and saturation flow rate), and traffic signal characteristics (controller type, cycle length, turn type, full yellow and red time, and total split). These data were entered into Synchro 11 software to analyze traffic performance and calculate indicators such as average delay, level of service (LOS), and volume-to-capacity ratio. The model was calibrated by adjusting the ideal saturation flow rates according to HCM adjusting factors and signal timing to match field measurements. The Aden and Sana'a intersections and the Tobji and Shalgiyah intersections were drawn using Synchro 11 software, as shown in Figs. 3 (a), (b), (c), and (d).

Traffic volumes for the four selected intersections were calculated using data from surveillance camera recordings. Peak hours were determined based on the highest traffic flow rates recorded during the monitoring periods, and this data was incorporated into the analysis. The results showed variations in traffic volumes between intersections, with the Al-Shaljiya Intersection recording the highest traffic volume at 3,438 vehicles per hour, while the remaining intersections experienced relatively high volumes, reflecting the significant operational pressure on this network. The data collected at peak times is shown in Fig. 4

The peak hour factor (PHF) is the hourly traffic volume divided by the maximum 15-min*4 flow. It is a statistically significant indicator in transportation project analysis for traffic modeling and flow assessment purposes. The calculated PHF values ranged from 0.87 to 0.96, as shown in Fig. 5, for all approaches at the intersections on 14th July Road. These values reflect variations in the regularity of vehicle flow during peak hours. Higher values (0.95 and above)



(a) (b) (c) (d)

Fig. 3 Synchro models of the studied intersections: (a) Aden (b) Sana'a (c) Tobji (d) Al-Shalgiya intersection

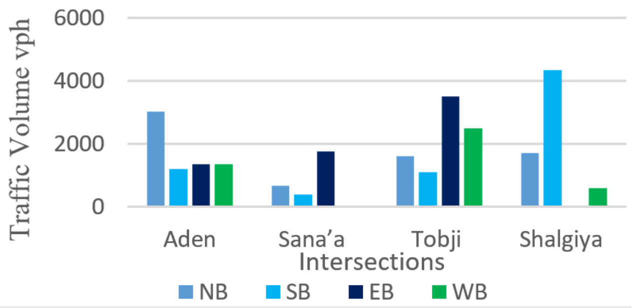


Fig. 4 Traffic volume at peak hour

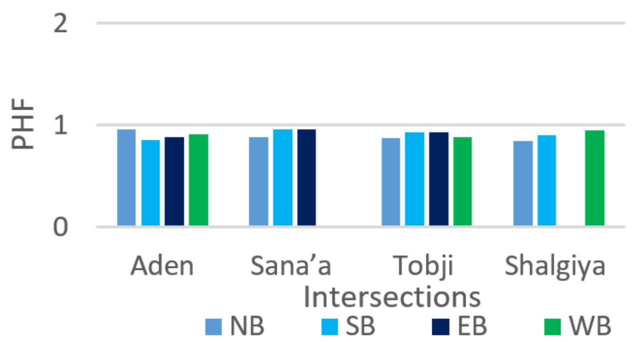


Fig. 5 PHF for all selected intersections at 07:30-08:30 a.m.

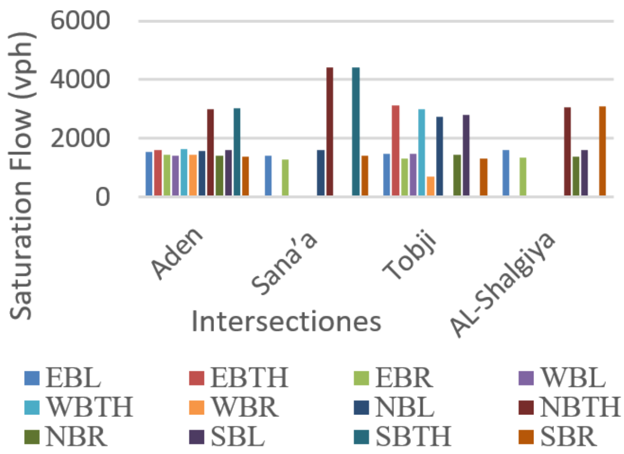


Fig. 6 Saturation flow for all selected intersections at 7:30-8:30 a.m.

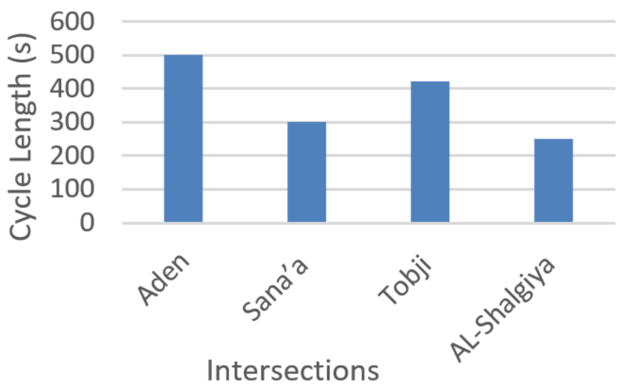


Fig. 7 Cycle length of the signalized intersections

indicate stable and regular flow, while lower values (0.85–0.90) reflect periods of heavy traffic congestion during an hour. This variation is attributed to the nature of site activity, traffic volume density.

The saturated flow was not measured in the field due to the difficulty of achieving a constant saturated flow at the start of the traffic grace periods under local traffic conditions. This is due to the significant variability in driver behavior, pedestrian interference, side stops, and cycle length. Instead, the baseline saturated flow reference value proposed in the HCM Manual (1900 vehicles/h/lane) was adopted and adjusted using the manual's adjustment factors so that the final values reflect actual site conditions. (number of one-way lanes, percentage of heavy vehicles, lane width, bus stop, zone type, parking maneuvers, and turning traffic), as shown in Fig. 6.

Intersections in the study area operate with a pre-timed traffic signal system. Fig. 7 shows the cycle time for each intersection. In this work, the traffic officer determined the cycle time and signal phase distribution for intersections, and according to the Highway Capacity Manual (Transportation Research Board, 2010), the optimal cycle time depends on traffic volume and the number of phases. In the case of the intersections, it was shown that the cycle time field to achieve acceptable capacity exceeded the recommended engineering limits (typically 60–180 sec for urban intersections). This was due to the significantly higher flow rate (V) compared to the available capacity (C) and the high V/C (volume-to-capacity ratio). Therefore, the traffic management increased the cycle time, which aligns with the operational objective of reducing the number of vehicle stops and increasing the saturation rate per traffic movement, especially given the lack of immediate engineering alternatives such as the construction of additional lanes or overpasses.

3 Results and discussions

It is necessary to simulate the real movement to examine the current state of traffic operation methods and geometry on traffic flow performance on the 14th July arterial.

3.1 Evaluation of the 14th of July Arterial intersections under existing conditions

Using the engineering traffic characteristics and traffic signal characteristics of the research intersections with the Synchro 11 software, the analysis results appear in Table 1, showing that most intersections within the study area operate above degree of saturation (V/C)>1 and on a level of service (F), with a large amount of delay outside the acceptable limit according to the HCM guide, despite exceeding

Table 1 The Operational analysis results for the existing condition of four intersections

Intersection	Total delay (*s/veh*)	Degree of saturation (*V/C*)	LOS
Aden	302.8	1.98	*F*
Sana'a	56.7	0.82	*E*
Tobji	235.2	1.77	*F*
Shalgiya	161.2	1.48	*F*

the permissible limit of the cycle time, but this was not sufficient to reduce the delay levels or to improve the operational indicators, which reflects the need for engineering interventions to improve the condition of the intersections.

3.2 Evaluation of the 14th of July Arterial highway under operating conditions

The 14th July Arterial Road is considered to have interrupted flow, which is more complex to analyze than an uninterrupted flow because the time dimension is affected by conflicting traffic. The presence of traffic lights affects road operational conditions, such as traffic flow, flow rate, departure times, control variables, and other parameters. Therefore, the poor intersection performance reflects the poor operational conditions of the road links shown in Fig. 8. For both the northbound and southbound directions, as shown in Table 2, most sections of the road fall into Level *F*, which occurs when the demand flow in one or both directions exceeds the section's capacity. Operating conditions are unstable, and severe traffic congestion prevails on the 14th July Arterial Road. In addition, travel time is long during commuting. This is reflected in the performance measurement of effective

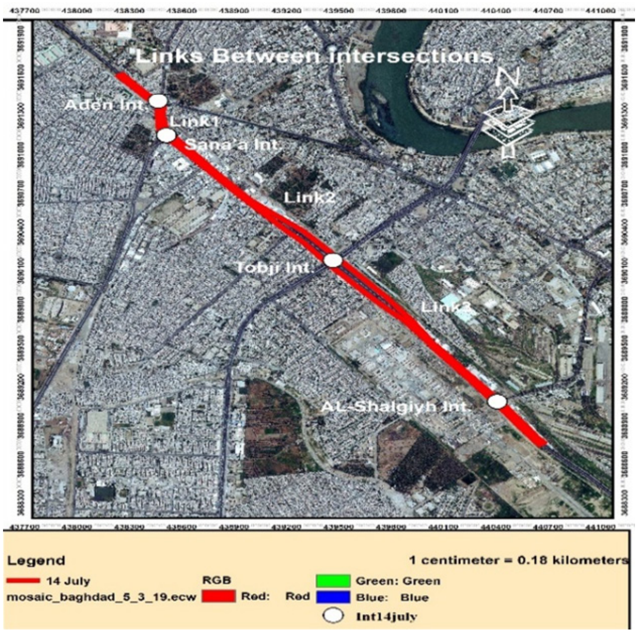


Fig. 8 Links to the 14th July Arterial

Table 2 The evaluation of the arterial highway under existing operating conditions

North Bound (NB), Travel time, LOS				
Link	Location	Travel time (s)	LOS	
1	Between Aden and Sana'a	222.3	*F*	
2	Between San'a and Tobji	231	*E*	
3	Between Tobji and Shalgiya	407.3	*F*	
South Bound (SB), Travel time, LOS				
Link	Location	Travel time (s)	LOS	
1	Between Aden and Sana'a	159.2	*F*	
2	Between San'a and Tobji	497.0	*F*	
3	Between Tobji and Shalgiya	333.7	*F*	
Measures of Effectiveness (MOEs) for road				
Link	Total delay/veh (*s/v*)	Fuel consumed (*l*)	CO (kg)	Performance index
North	192	1177	21.89	280.6
South	208	1728	32.13	341.5
Total	201	2905	54.02	622.2

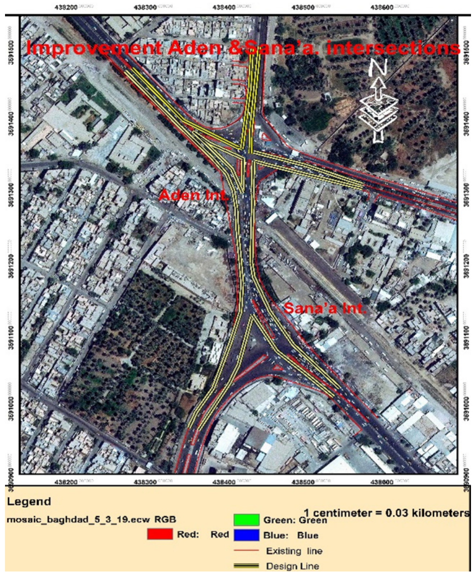
indicators (MOEs) shown in the latter part of Table 2, indicating that under the current operating conditions of the 14th July Arterial Road, its performance is deteriorating due to heavy traffic. High Performance Index (PI) values were recorded in both the northbound and southbound directions, indicating severe traffic congestion and insufficient traffic capacity (high saturation). In addition, the total delay per vehicle is high, resulting in a poor Level of Service (LOS), which reached the LOS level *F* at most locations. High fuel consumption of 2,905 l/h and CO_2 emissions of 28.02 kg/h were recorded for the same studied sections of road, indicating that energy consumption and greenhouse gas production increase with increased traffic volume and delays. These values confirm that traffic congestion and spillback between intersections lead to frequent vehicle stops/starts, increasing fuel consumption and emissions per unit time, negatively impacting air quality in nearby urban areas.

4 Improvements of the 14th July Arterial

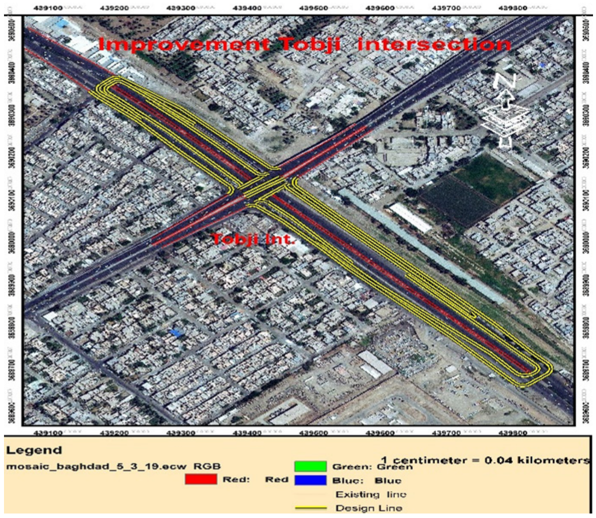
To improve mobility in the urban transport system and reduce passenger delays, signal control is optimized through various measures. These include implementing advanced signal control systems, optimizing traffic signal timing, or changing the geometric design of the intersection, such as constructing a two-way overpass or separating left-hand traffic from the intersection. *V*/*C* can be improved to provide a better level of service. These solutions aim to reduce delays caused by traffic congestion in the road network. As the 14th of July Road is a major thoroughfare in western Baghdad, it experiences high traffic volumes and prolonged delays, despite signal timing to discharge volume. Synchro reports show traffic volumes exceeding intersection capacity, with delays reaching more than 300 sec/vehicle in some locations. The level of service for the road between intersections remains in Category *F*, indicating severe congestion and low network efficiency. These conditions demonstrate that traditional solutions such as adjusting signal timings or surface engineering improvements are insufficient to address the root problem, which lies in the limited capacity and spatial overlap between different traffic flows. Therefore, an engineering solution was adopted by constructing overpasses to separate traffic levels, eliminating overlap points, increasing capacity, and effectively reducing delays, and reducing fuel consumption and CO_2 emissions, achieving dual benefits on both the traffic and environmental levels. This constitutes a permanent and sustainable solution that goes beyond the limitations of electronic signal control. As shown in Figs. 9 (a) to (c), overpasses were constructed at road intersections. The first project, Flyover, is a two-level grade-separated urban intersection as shown in Fig. 9 (a) that connects the first overpass, Baghdad-Mosul Road and Al-Nawab Street, to Al-Rabi' Street and 14 July Street (Al-Muthanna Airport Road). The second overpass connects the Baghdad-Mosul Road to Al-Badala Street, leading to the Al-Atifa area.

The second project consists of two loop ramps as seen in Fig. 9 (b). This design falls under the category of grade-separated interchange. This engineering solution aims to reduce delays and stops for vehicles coming from the main axes. It also enhances operational efficiency by providing free traffic flow without the need for traffic signals. One of the ramps is approximately 550 m long, and the other is approximately 950 m long.

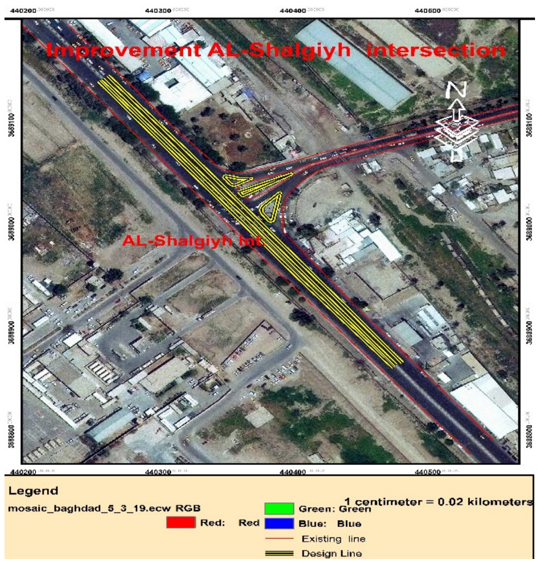
The third project to implement an overpass over 14th July Road, as shown in Fig. 9 (c) is an engineering solution with two lanes in each direction, raising the direction of traffic through movement (northbound and southbound) from the intersection on 14th July Road, causing increased capacity on it and a reduction in congestion on the Karkh side.



(a)



(b)



(c)

Fig. 9 Improvement at the studied intersections: (a) Aden and Sana'a; (b) Tobji; (c) Shaljiyah

4.1 Evaluation of the 14th of July Arterial intersections after improvement

To evaluate the performance of the improved intersections after taking into account the proposed improvements and traffic signals, an operational analysis was conducted using Synchrono11 software to measure the performance of the intersections and corridors, as shown in Table 3. Adopting the above proposals resulted in a reduction in travel time, improved service levels, and achieved road sustainability through Measures of Effectiveness (MOEs).

4.2 Evaluation of the Arterial under the improved conditions

Adopting the above proposals and their effect on the 14th July road's performance resulted in a reduction in travel time, improved level of service, and achieved road sustainability through Measures of Effectiveness (MOEs) as shown in Table 4.

After Improvement results for Arterial Link (1), Link (2), and Link (3) are shown in both directions, respectively, in Table 5, Figs. 10 and 11.

Table 3 Evaluation of the intersections under improvement conditions

Intersection	Total delay	LOS	Degree of saturation (*V*/*C*)
Aden	50.4	*D*	1.07
Sana'a	12.6	*B*	0.84
Tobji	16.4	*B*	0.95
AL-Shalgiya	12.7	*B*	0.88

Table 4 Evaluation of the corridor under the improved conditions

North Bound (NB), Travel time, LOS			
Link	Location	Travel time (s)	LOS
1	Between Aden&Sana'a	117.6	*F*
2	Between San'a&Tobji	107.7	*B*
3	Between Tobji & Shalgiya	147.2	*B*
South Bound (SB), Travel time, LOS			
Link	Location	Travel time (s)	LOS
1	Between Aden&Sana'a	16.9	*B*
2	Between San'a&Tobji	115.4	*B*
3	Between Tobji & Shalgiya	117.4	*A*

North Bound (NB), Measures of Effectiveness (MOEs)				
Link	Total delay/veh (*s*/*v*)	Fuel consumed (*l*)	CO (kg)	Performance index
North	33	204	3.79	13.3
South	24	198	3.69	10.4
Total	41	402	8.71	23.7

Table 5 Travel time reduction after the implementation of the improvement

Link	Direction	Original time (s)	Improved time (s)	Percentage reduction
1	North Bound	222.3	117.6	47%
	South Bound	159.3	16.9	89%
2	North Bound	231	107.7	53%
	South Bound	497	115.4	76%
3	North Bound	407.3	147.2	63%
	South Bound	333.7	117.4	64%

− (+) Sign indicates if the travel time increased

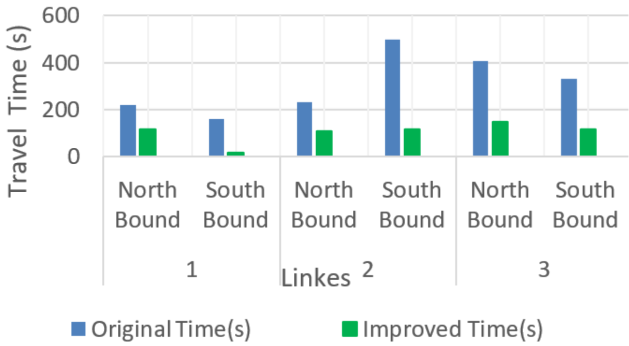


Fig. 10 Travel time comparison of 14th July Arterial links before and after improvement

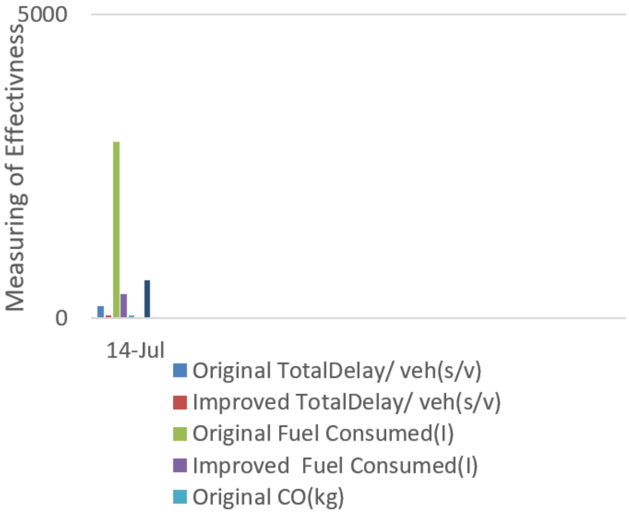


Fig. 11 Measures of Effectiveness (MOEs) comparison of 14th July Arterial before and after improvement

As shown in Tables 3, 4, and 5, the traffic performance analysis results for the arterial and its associated intersections showed a significant improvement following the implementation of the overpass intersection development projects. The improvement included a number of key intersections along the arterial, where average delays decreased and levels of service (LOS) improved for all traffic movements in both the north and south directions during peak hour. The traffic volume-to-capacity ratio (*V*/*C*) also improved overall, decreasing from critical values of 1.98 at some intersections to around 1.07, reflecting the reduction in traffic congestion and increased intersection capacity. Despite the persistence of some high values, the overall travel time decreased significantly, resulting in improved road performance across all junctions. Additionally, the performance index (PI) showed a significant improvement, reflecting the effectiveness of engineering interventions in improving flow and reducing traffic interference. The engineering projects, particularly the construction of bridges, contributed to reducing traffic congestion and improving flow, which positively impacted fuel consumption and carbon dioxide emissions, thus improving the area's environmental impact. These results reflect the effective role of the developed projects in enhancing the operational efficiency of both the intersections and the main road within the scope of the study.

5 Conclusions

The 14th of July Urban Road, with its intersections, is severely congested during the morning peak hour (7:30–8:30 a.m.), becoming a significant traffic demand issue. This is one of the most attractive areas in western Baghdad, as it is the main route for the distribution of trips to western Baghdad, in addition to the mixed land use surrounding this major urban corridor. From the previous results, the following concluding observations can be drawn: Intersection delays negatively impact road capacity, with delay values for the four intersections ranging from 8.302, 56, 235, and 161 sec, respectively, affecting travel time and road LOS. After implementing improvements at the four intersections, the situation became more sustainable, as the improvements showed that travel time had been reduced at all three links, with travel time reductions ranging from 47% to 89% in both directions. Furthermore, reducing intersection delays resulted in a significant improvement in the Measures of Effectiveness (MOEs) on the 14th of July Road. This research aims to address this existing traffic problem by analyzing the current performance of the intersection and proposing practical engineering solutions to alleviate congestion and improve the level of service. Although the results demonstrated the operational effectiveness of the proposed solutions, estimating their cost and implementation timeframe was not included within the scope of this study, which requires additional research to assess economic feasibility. Projects underway or planned in the study area, such as the construction of overpasses or infrastructure improvements, can also be integrated within the framework of comprehensive solutions to address traffic congestion.

6 Recommendations

Although the current study primarily focuses on improving the performance of traffic intersections on 14th of July Road, it is important to note some essential recommendations, including:

- Future researchers are advised to expand and improve data collection methods in line with technological developments, to enhance the accuracy of traffic simulation models and their compatibility with changing traffic conditions, while taking into account practical constraints in the study environments.
- It would be useful to study the impact of using intelligent traffic signal systems and measure their effect on improving traffic flow and reducing delays in similar urban areas and integrating dynamic traffic modeling for evaluating long-term impacts.
- Although the current study focused primarily on the operational and technical aspects of improving intersection performance, economic and environmental evaluations and project implementation duration are important dimensions that require specialized future studies to enhance understanding of the overall feasibility of the proposed traffic solutions.
- Improving public transportation services is a sustainable solution that significantly contributes to mitigating traffic problems and negative environmental impacts in the long term. Therefore, researchers and decision-makers are advised to consider developing public transportation networks as part of comprehensive strategies for traffic management and improving the quality of the urban environment.

References

Abdulwahab, A. M., Bader, M. A. (2020) "Sustainable Transportation Strategies in Baghdad City: Shaab–Selekh Intersection", Diyala Journal of Engineering Sciences, 13(1), pp. 66–77. https://doi.org/10.24237/djes.2020.13107

Alkaissi, Z. A. (2022) "Traffic simulation of a continuous flow intersection with displaced left-turn: a case study", Journal of Engineering and Applied Science, 69(1), 39. https://doi.org/10.1186/s44147-022-00091-7

Asgarpour, S., Hartmann, A., Gkiotsalitis, K., Neef, R. (2023) “Scenario-based strategic modeling of road transport demand and performance”, Transportation Research Record, 2677(5) pp. 1415–1440. https://doi.org/10.1177/03611981221143377

Flaah, W., Ajam, H. K. (2024) "Simulation and Evaluating of Traffic Flow for Hillah City Using VISSIM and GIS Programs", IOP Conference Series: Earth and Environmental Science, 1374(1), 012009. https://doi.org/10.1088/1755-1315/1374/1/012009

Hameed, A. N. (2013) "Evaluating and Improving the Efficiency of Intersection of Freeway Off-Ramps with Arterial Roadway", Engineering and Technology Journal, 31(21), pp.28–37. https://doi.org/10.30684/etj.2013.83892

Hasan, J. N., Hussein, N. A. (2022) "Traffic Assessment and Optimization at Signalized Intersections: A Review Study", Journal of Duhok University, 25(1), pp. 124–141. https://doi.org/10.26682/sjuod.2022.25.1.15

Kareem, M. L., Alkaissi, Z. A. (2024) "Traffic State Comparison of Signalized Intersections Using SIDRA and SYNCHRO Software", Journal of Engineering and Sustainable Development, 28(4), pp. 541–549. https://doi.org/10.31272/jeasd.28.4.13

Mohammed, A. A. B., Bughrara, N. F. A., Tarhuni, F., Alsaiti, A. M. A. (2024) "Optimizing the Performance of Signalized Intersections Using Synchro Simulation Software", In 2024 IEEE 4th International Maghreb Meeting of the Conference on Sciences and Techniques of Automatic Control and Computer Engineering (MI-STA), Tripoli, Libya, pp. 631–636. ISBN 979-8-3503-7264-9 https://doi.org/10.1109/mi-sta61267.2024.10599737

Rajab, N. A., Awad, H. A., Alrawi, F. (2022) "Evaluation the Level of Service of Signalized Intersection: Al-Amreia Intersection as a Case Study", In Proceedings of the 8th International Conference on Civil Engineering, Jiangxi Province, China, pp. 18–30. ISBN 978-981-19-1259-7 https://doi.org/10.1007/978-981-19-1260-3_3

Transportation Research Board (2010) "HCM 2010 Highway Capacity Manual", National Academies Press. ISBN 978-0309160773

Udomsilp, K., Arayakarnkul, T., Watarakitpaisarn, S., Komolkiti, P., Rudjanakanoknad, J., Aswakul, C. (2017) "Traffic Data Analysis on Sathorn Road with Synchro Optimization and Traffic Simulation", Engineering Journal, 21(6), pp. 57–67. https://doi.org/10.4186/ej.2017.21.6.57

Wang, W., Wu, X. (2024) "Research on the green wave control of signalized intersections of the Longmen Road in Tianjin", In Seventh International Conference on Traffic Engineering and Transportation System (ICTETS 2023), Dalian, China, 13064, pp. 410–415. https://doi.org/10.1117/12.3015872

Ziboon, A. R. T., Qasim, Z. I., Yousif, M. A. (2019) "Traffic Performance Evaluation and Analysis of Al-Fallah Intersection in Baghdad City Utilizing Synchro.10 Software", Journal of Engineering and Sustainable Development, 23(6), pp.25–34. https://doi.org/10.31272/jeasd.23.6.3