Evaluation of the Proposed Ring Road as a Strategic Solution for the Enhancement of Urban Mobility and Traffic Flow in Hilla City

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ABSTRACT

This study proposes the construction of a 87 km ring road surrounding Hilla city in Iraq, as a strategic solution to mitigate urban traffic congestion and improve regional mobility. By integrating Geographic Information Systems (GIS) and cost-benefit economic analysis, this study shows how diverting external traffic from the urban core can optimize network performance. Field data, including traffic counts, radar speed profiles, and origin-destination surveys, were used to assess the current conditions and project traffic demand up to 2035. The results indicate a projected improvement in Level of Service (LOS) from F to B/C, an increase in internal network speed from 20–25 km/h to 35–40 km/h, and a 40% reduction in average vehicle delay. Economically, the project yields a Net Present Value (NPV) of 98.6 million USD, a Benefit-Cost Ratio (BCR) of 1.537, and a payback period of 5.87 years. The Effectiveness Index (EI) of 0.48 further consolidates the technical and economic viability. This research provides a replicable framework for strategic infrastructure planning in secondary cities across Iraq and comparable urban settings in developing nations.

Keywords-ring road; urban traffic congestion; economic feasibility; Level of Service (LOS)

I. INTRODUCTION

Hilla city, located at the crossroads of Iraq's major inter-governorate corridors of Baghdad, Karbala, Najaf, and Diwaniyah, faces growing urban traffic congestion due to the rapid urbanization, population growth, and regional connectivity demands. The existing road network in Hilla, particularly 60th Street, operates under severe strain, exhibiting low LOS and high travel delays, especially during religious events and peak hours. Previous interventions, such as road widening and signal timing adjustments, have offered only temporary relief, highlighting the need for a sustainable and strategic mobility solution.

Field observations and previous studies have confirmed that the concentration of external vehicular movement within Hilla's urban core aggravates traffic conflicts, undermines road safety, and degrades environmental quality. During peak periods, the flow along 60th Street is reduced to stop-and-go conditions, particularly during religious events and national holidays when the visitor volumes surge. Past interventions, such as lane widening and traffic signal optimization, have proven insufficient for long-term relief, highlighting the need for a macro-scale infrastructure strategy [1].

Authors in [2] investigated the LOS conditions on a portion of the 60-m ring road in Erbil City. The study found that despite the road's wide geometry, the presence of numerous branch roads significantly reduced the average travel speed to 19 km/h, resulting in a LOS of category F. Their analysis emphasized the critical impact of turning movements and traffic conflict points on the operational efficiency. They proposed geometric improvements, such as the construction of bridge ramps, to enhance the LOS and reduce congestion.

Globally, ring roads have proven effective in mitigating similar challenges by diverting external-to-external traffic away from congested city centers. In cities like Madrid and Beijing, the implementation of ring roads has reduced CO_2 emissions and improved travel time efficiency [3, 4]. In the United States, beltway systems support regional circulation and economic decentralization [5]. Regional studies in Iraq, such as those in Baqubah and Najaf, also underscore the potential of ring roads to yield high BCRs and enhance operational efficiency [5].

GIS have become central to modern transportation planning, enabling optimized route alignment and land-use integration. In Hilla, prior GIS analyses revealed fragmented road development and emphasized the need for coordinated network expansion [6]. Authors in [7] assessed four route choice models using microscopic simulations in a dynamic traffic assignment framework. Their study highlighted the importance of parameter calibration in improving route choice accuracy for traffic impact analysis.

Economic feasibility, often measured using indicators, such as NPV and BCR, remains critical for infrastructure project evaluation. Studies from Indonesia and Iraq highlight the necessity of incorporating risk factors, such as variable demand and underestimation of costs, into feasibility models [8, 9]. Additionally, sustainability metrics, such as the Integrated City Street Transport (ICST) index, provide a holistic view of the environmental and mobility performance.

Despite these global and regional insights, the existing literature often treats spatial, economic, and operational dimensions separately, without synthesizing them into an integrated planning framework. There is a notable gap in comprehensive studies addressing induced demand, environmental constraints, and multi-source data integration in secondary Iraqi cities like Hilla.

Accordingly, this study aims to bridge these gaps by proposing and evaluating an 87 km ring road around Hilla through a multidisciplinary approach that integrates GIS-based spatial analysis and economic feasibility assessment. This study provides a replicable infrastructure planning and decision-making model for similarly scaled urban environments. This research provides a local case study illustrating how the infrastructure interventions can directly influence traffic flow and roadway performance. Furthermore, the study integrates a forward-looking component, projecting future traffic volumes up to 2035 based on an established compound growth rate of 2.5% per annum, a rate validated in recent Iraqi transport planning literature [8, 10]. These projections display the enduring utility of the proposed bypass under increasing urban and regional mobility demands. The future scenario analysis confirmed that the proposed infrastructure would alleviate the internal congestion significantly, improve the overall LOS across the network, and enhance the operational sustainability through reduced emissions and improved travel times.

II. STUDY AREA AND DATA COLLECTION

Hilla occupies a strategic geopolitical position in central Iraq, serving as a regional logistics and commuting hub. The city's radial urban layout renders it a critical junction in the national mobility framework. However, the absence of an orbital traffic facility has exacerbated inner-city bottlenecks and disrupted the regional flow. The proposed ring road aims to restructure the traffic distribution by providing a peripheral conduit aligned with natural and administrative boundaries, avoiding ecologically sensitive and densely populated zones through advanced GIS-based corridor optimization. The study area is characterized by mixed land use, including residential, agricultural, and institutional zones, which present both logistical challenges and opportunities for optimized alignment. Additionally, the proximity to major river systems and historical zones necessitates sensitivity in planning and execution. The topographical flatness of the terrain facilitates the road construction but also demands advanced drainage planning due to seasonal flooding. The demographic and land-use diversity in the area further reinforces the importance of a multidisciplinary planning approach that integrates spatial intelligence with engineering foresight.

Figure 1 illustrates the central urban network of Hilla, identifying critical arterial roads including 60th Street, 40th Street, Al-Atbaaba Street, Al-Mahkamah Street, and major regional connectors, such as Baghdad, Karbala, Najaf, and Diwaniyah Roads. These road segments were selected for detailed traffic performance assessment as they represent key nodes of congestion and vehicular flow within the city's transportation grid.

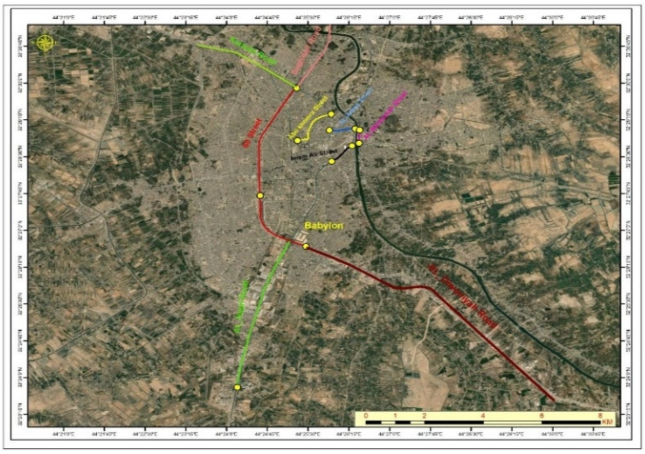

Fig. 1. Spatial distribution of major arterial roads and streets in central Hilla city.

Data were collected using a combination of video surveillance, radar speed gun devices, and an Origin–Destination Survey (O-D Survey). High-resolution video cameras were strategically installed at multiple intersections and along arterial roads to capture the real-time traffic flow. These cameras operated during both peak and off-peak hours over multiple consecutive days, ensuring accurate representation of diurnal and weekly traffic variations. The video footage was analyzed frame-by-frame to derive traffic volume counts, vehicle classifications, and intersection delay times.

The O-D Survey provided complementary insights into the vehicle movement patterns. It was designed to capture critical trip characteristics, including vehicle type, origin and destination points, trip purpose, trip duration, average speed, frequency of road use, and driver perceptions regarding traffic delays and support for the proposed ring road. The data from the O-D Survey significantly enhanced the understanding of the traffic flows, particularly the proportion of external-to-external trips, thereby justifying the proposed ring road's role in diverting through-traffic away from the congested urban core. Together, these comprehensive data collection techniques provided a robust, evidence-based foundation for the traffic analysis, economic evaluation, and simulation modeling efforts of this study.

III. METHODOLOGY

This study employed a systematic and multidisciplinary approach to design and evaluate an alternative ring road for Hilla, integrating spatial analysis, traffic simulation, and economic feasibility assessments. The methodology was structured to ensure scientific rigor, replicability, and practical relevance. This study followed a sequential process that included data collection, analytical tool selection, and financial evaluation.

A. Conceptual Assumptions

The study was based on the assumption that a well-designed ring road can significantly alleviate congestion, enhance traffic flow, and improve the LOS in Hilla. Several foundational principles guided this research:

- GIS provided a robust platform for identifying optimal road alignments while minimizing land acquisition conflicts and environmental disruption.
- Economic feasibility assessments, including NPV and BCR, provided an objective means of evaluating the financial sustainability and long-term benefits of infrastructure investment.
- Side friction impacts (such as pedestrian movements, informal parking, and commercial activities) were critical in assessing the road capacity and vehicular throughput and must be incorporated into traffic performance models.

These assumptions provided the theoretical framework that justifies the selection of the research methods and analytical techniques.

B. Sampling Method and Data Collection

A multi-method sampling approach was employed to ensure data validity, accuracy, and representativeness. This study integrated both primary and secondary data sources, classified as follows:

- Traffic volume and speed surveys: Video cameras were installed at critical intersections along 60th Street, 40th Street, Al-Atbaaba Street, and Al-Mahkamh Street to monitor the traffic movement. Data were collected during peak and off-peak hours over multiple days to capture hourly and daily traffic variations.
- GIS mapping and spatial analysis: Land use data, road network configurations, and environmental constraints were obtained from municipal databases, OpenStreetMap, and satellite images. These datasets were analyzed using ArcGIS to map the potential ring road alignments.
- Economic data: Cost estimates for road construction, land acquisition, and long-term maintenance were derived from historical infrastructure projects in Iraq and adjusted using inflation-corrected models to reflect the current market conditions.
- O-D survey: A structured questionnaire was administered at strategic entry points during peak hours to gather data on vehicle types, trip origins and destinations, travel purposes, duration, average speeds, frequency of road use, perceived delays, and driver attitudes towards the proposed ring road. The survey aimed to quantify external-to-external trip patterns, essential for assessing the potential traffic redistribution and the impact of the ring road on urban congestion.

This comprehensive data collection strategy ensured that all key variables influencing urban traffic flow were empirically analyzed.

IV. DESCRIPTION OF ANALYTICAL TOOLS

Three core analytical tools were selected based on their scientific credibility, practical application, and replicability in urban transportation planning.

A. Geographic Information Systems

GIS was used for route optimization. GIS-based Multi-Criteria Decision Analysis (MCDA) was applied to evaluate different ring road corridors based on factors, such as land constraints, environmental sensitivity, and traffic connectivity. Additionally, GIS was used for spatial visualization by creating topographic and network maps to assess potential urban displacement risks and ensure seamless integration with existing road infrastructure.

B. Economic Feasibility Analysis

The financial sustainability of the proposed ring road was assessed using NPV to determine the long-term economic viability of the project over a 25-year evaluation period, BCR to assess whether the expected economic benefits outweigh the project costs, ensuring Return On Investment (ROI), and sensitivity analysis by modeling different scenarios to test the project feasibility under varying fuel prices, construction costs, and traffic demand growth rates.

By bridging the gap between spatial planning, traffic modeling, and financial forecasting, this research provides a strategic roadmap for policymakers and urban planners, facilitating evidence-based decision-making for sustainable transportation development.

V. DESCRIPTION OF THE PROPOSED ROAD

Figure 2 depicts the geographic scope of the study area, focusing on the central districts of Hilla City and the proposed alignment of the 87 km ring road. The map highlights the main arterial roads (Baghdad, Karbala, Najaf, and Diwaniyah Roads) and the proposed ring road corridor (marked in white), which is intended to divert through traffic from the city center. The selected urban corridors under study are marked with colored lines and key node identifiers. The insets on the right of Figure 2 provide representative street-level images of the existing conditions along major roadways, such as Abo Komra 40 Street and Al-Adeala 60 Street, offering a contextual visual reference to the current urban traffic conditions.

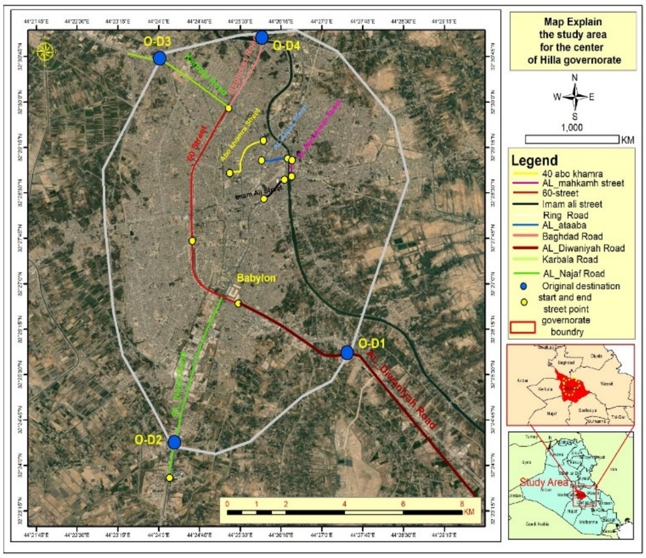

Fig. 2. Spatial distribution of key urban corridors and proposed ring road alignment in Hilla.

The proposed 87 km dual-carriageway ring road around Hilla is envisioned as a strategic intervention to decongest the urban core and enhance the regional mobility. Designed in alignment with international highway engineering standards, the road features four lanes, each 3.75 m wide, with a design speed of 80 km/h. The project scope includes 4 major bridge structures and 33 aqueducts engineered to mitigate hydrological disruptions and maintain environmental continuity. The design prioritizes minimal land acquisition and ecological sensitivity, especially in traversing the narrowest portions of the Hilla river, thereby reducing the construction costs and impacts.

The route commences along Najaf Road near the University of Babylon (geographical coordinates: 32.4018589, 44.403988). From this origin, the alignment extends eastward, bypassing the northern edge of the Sport City and maintaining a semi-elliptical arc that circumvents the densely populated urban nucleus. The route intersects with the Al-Qasim district road at coordinates 32.426112, 44.465024, facilitating regional connectivity. The first river crossing is strategically placed at coordinates 32.436904, 44.473998, where the Hilla river narrows to approximately 75 m, offering structural and financial advantages.

Subsequently, the road advances through peri-urban agricultural zones before crossing Baghdad Road and an adjacent railway line (32.584114, 44.424933). It then curves southwestward through areas characterized by palm orchards and aquaculture facilities. A second crossing over the Hilla river is incorporated at a hydrologically optimal site near coordinates 32.561971, 44.402102, selected for its narrower width to minimize the structural span and associated costs. The route then proceeds through Karbala Road at coordinates 32.520742, 44.372891, maintaining spatial coherence with the surrounding transportation grids.

The final segment veers south, aligning with Karbala Road at coordinates 32.520742, 44.372891, then loops eastward to complete the circuit. This terminal alignment skirts the University of Babylon's planned future expansion area and rejoins Najaf Road near coordinates 32.370755, 44.399491, ultimately terminating at Al-Qasim District Road (32.405561, 44.487805). The route not only ensures uninterrupted vehicular flow, but also preserves corridors for future capacity expansion.

VI. ECONOMIC FEASIBILITY

A. Baseline Traffic Conditions

Field data for a representative 5 km segment of 60th Street yielded an average speed of about 15 km/h during the peak hours, a current capacity of about 2000 vehicles per hour (veh/h), and a baseline time, T1, of 15 min, estimated from:

$$T1 = \frac{\text{distance}}{\text{speed}} = \frac{5\text{ km}}{20\text{ km/h}} = 0.25\text{ h} = 15\text{ min} \quad (1)$$

These conditions confirm that 60th Street operates at a very low LOS (F category) with heavy congestion and prolonged travel times. The observed improvements in LOS across critical corridors were evaluated using the criteria defined in the Highway Capacity Manual (HCM) [11], ensuring the standardization and global comparability of the results.

These improvements reflect a significant enhancement in the overall LOS, from F to approximately B, resulting in smoother traffic flow and reduced delays.

B. Economic Analysis Results

1) Cost Estimation

The project is estimated to cost 183.4 million USD (covering construction, maintenance, and land acquisition).

2) Benefit Estimation

A major component of the annual economic benefit is derived from the time savings resulting from improved traffic conditions. This estimation relies on field-observed traffic volumes, particularly along 60th Street, which functions as the primary arterial corridor in Hilla. The daily trip count of 95000 vehicles was derived from official traffic statistics reported by the Ministry of Construction and Housing / Directorate of Roads and Bridges in Babylon. The data reflect sustained vehicular load patterns across multiple observational intervals, highlighting the strategic importance of 60th Street in the city's overall traffic dynamics.

If we assume 95000 trips/day, a time of 24 min or 0.4 h saved per trip, a value of time of 1.5 $/h, and 365 days/year, then the annual economic benefit can be estimated by:

$$\text{Annual time savings (\$)} = \frac{\text{trips}}{\text{day}} \times \text{time saved (h)} \times \text{value of time}\left(\frac{\$}{\text{h}}\right) \times \frac{\text{days}}{\text{year}} \approx 21\text{ million \$ annually} \quad (2)$$

To ensure a conservative and realistic financial analysis, a portion of this estimate was adjusted to account for variability, yielding a final annual economic benefit of 20 million USD.

3) Payback Period

The payback period was estimated at 9.17 years by:

$$\text{Payback period} = \frac{\text{total project cost}}{\text{annual benefit}} = \frac{183.4 \text{ million } \$}{20 \text{ milliom } \$/\text{year}} = 9.17 \text{ years} \quad (3)$$

4) NPV Calculation

Assuming a discount rate of r = 5% and a project lifespan of n = 25 years, the Present Value (PV) of the Annuity Factor (AF) is given by:

$$AF = \frac{1-\left(\frac{1}{(1+r)^n}\right)}{r} = \frac{1-\left(\frac{1}{(1.05)^{25}}\right)}{0.05} \approx 14.1$$

$$PV \approx 20 \text{ million } \$ \times 14.1 \approx 282 \text{ million } \$ \quad (4)$$

Then the NPV is:

$$NPV = PV - \text{total project cost} = 282 \text{ million } \$ - 183.4 \text{ million } \$ = 98.6 \text{ million } \$ \quad (5)$$

5) BCR Calculation

The BCR is determined as:

$$BCR = \frac{PV}{\text{total project cost}} = \frac{282 \text{ million } \$}{183.4 \text{ million } \$} = 1.537 \quad (6)$$

A BCR greater than one confirms the economic viability of the proposed ring road.

The financial feasibility of the proposed 87 km ring road was comprehensively assessed using a cost-benefit analysis framework spanning a 25-year project lifecycle. The total estimated cost of 183.4 million USD covers five major components: roadway construction (87.7 million USD), bridge infrastructure (28.9 million USD), aqueduct installations (21.7 million USD), scheduled maintenance (14.8 million USD), and residential compensation (30.3 million USD). These cost figures were benchmarked against comparable infrastructure projects in Iraq and adjusted to 2023 market values using the relevant inflation indices.

The annual economic benefits were primarily driven by time savings, fuel efficiency, accident risk mitigation, and environmental improvement. Based on the simulation outputs and traffic volume forecasts, the proposed ring road is expected to reduce the average trip time by 24 min across thousands of daily trips. Applying a conservative valuation methodology, the annual benefit was estimated to be 20 million USD.

The payback period, calculated as the ratio of the total cost to the annual benefit, is approximately 9.17 years, which is well within the acceptable threshold for large-scale public infrastructure projects. The NPV, calculated with a 5% discount rate over a 25-year horizon, amounts to 98.6 million USD, indicating strong long-term financial viability. The BCR was computed at 1.537, suggesting that for every dollar invested, the project yields 1.537 USD in return.

To ensure financial robustness, a sensitivity analysis was conducted by modeling adverse scenarios, such as a 20% increase in project costs and a 15% reduction in anticipated benefits. In all tested conditions, the BCR remained above 1.0, underscoring the resilience of the investment under economic uncertainty. Overall, the project presents a compelling economic case, aligning with strategic national goals for sustainable infrastructure development and enhanced urban mobility.

C. Effectiveness Index

To support robust infrastructure evaluation beyond traditional binary or categorical classifications, the present study used a composite metric, the EI, designed to quantify the integrated performance of a proposed project using a normalized scale ranging from 0 to 1. This index consolidates both operational improvements and economic returns into a single evaluation value, allowing a transparent comparison between alternatives under constrained resource environments. The expression for finding EI is presented in:

$$EI = \frac{(L_n + T_n + B_n)}{3} \quad (7)$$

where L_n is the normalized LOS improvement, T_n is the normalized travel time reduction, and B_n is the normalized BCR.

Setting $L_n = 0.6$ due to the improvement of LOS from F to B, $T_n = 0.33$ (travel time reduced from 15 to 10 min), and $B_n = 1.537/3 = 0.51$ (BCR normalized by benchmark value), an EI of 0.48 is obtained from:

An EI of 0.48 indicates a moderate-to-high level of performance across the technical and economic dimensions. Unlike isolated metrics, such as LOS or BCR, this integrated index provides a holistic and balanced view that accommodates trade-offs among various planning priorities. It serves as a strategic tool for urban planners and decision-makers to prioritize investments, quantify project efficiency under uncertainty, and ensure alignment with sustainability and equity.

VII. ANALYSIS OF PEAK TRAFFIC VOLUMES ON EXISTING ROADS

To accurately assess the performance of the urban road network in Hilla, traffic volume data were collected during two peak periods each day: from 7:00 to 9:00 AM and from 2:00 to 4:00 PM. These time intervals were selected to capture the most congested periods associated with work and school commutes. The data collection process utilized a combination of manual counting methods and fixed-position surveillance cameras installed at critical intersections. Manual counting teams recorded vehicular flows using standardized traffic tally sheets and classified vehicles into light vehicles, buses, and heavy trucks. Data were collected systematically on three alternating days each week (Sunday, Tuesday, and Thursday) across the month to ensure the coverage of the variable daily demand patterns. Each volume count was normalized to vehicles per hour (veh/h) for uniform comparison.

TABLE I. SPATIAL DISTRIBUTION OF KEY URBAN CORRIDORS AND PROPOSED RING ROAD ALIGNMENT IN HILLA CITY

Date	60th Street (Northbound)	60th Street (Southbound)	Baghdad Roadway	Karbala Roadway	Najaf Roadway	Diwaniyah Roadway	Al-Atbaaba Street	Al-Mahkamh Street
Sun 3-Nov	4973	4663	4229	3566	5426	3626	3383	3720
Tue 5-Nov	3990	3585	3340	2827	3184	2754	3378	3732
Thu 7-Nov	5080	4550	4349	3552	5344	3526	3396	3744
Sun 10-Nov	5014	4724	4182	3631	5399	3605	3558	3756
Tue 12-Nov	4851	4744	4201	3651	5336	3772	3360	3768
Thu 14-Nov	4970	4758	4037	3665	5268	3798	3450	3798
Sun 17-Nov	4970	4761	4302	3564	5516	3556	3468	3792
Tue 19-Nov	4959	4673	4257	3619	5370	3654	3486	3804
Thu 21-Nov	5048	4482	4218	3641	5352	3535	3504	3788
Sun 24-Nov	5056	4824	4317	3604	5139	3883	3522	3828
Tue 26-Nov	4816	4662	4339	3457	5620	3750	3540	3840
Thu 28-Nov	5025	4672	4265	3623	5540	3693	3472	3852
Maximum	5080	4824	4349	3665	5620	3883	3558	3852
Minimum	3990	3585	3340	2827	3184	2754	3360	3720
Average	4899	4592	4169	3533	5207	3595	3468	3792

Table I summarizes the adjusted peak traffic volumes for twelve major observation days in November 2024 across eight key corridors in Hilla. These include both the primary internal arterial routes (such as 60th Street in both directions) and four strategic external roads that connect the city to Baghdad, Karbala, Najaf, and Diwaniyah. Additionally, two important urban roads, Al-Atbaaba Street and Al-Mahkamh Street, were incorporated into the monitoring network to better represent the central area circulation. The data in Table I were refined by applying a predictive adjustment factor to account for the expected seasonal increases in traffic during November, ensuring that the volumes reflected realistic peak conditions. To enable a comparative analysis and ensure consistency with international traffic engineering practices, the conversion of heavy vehicles and buses to Passenger Car Units (PCUs) was performed using a standard equivalency factor. A coefficient of 1.8 was adopted based on the recommendations from the HCM [11].

From Table I, it is evident that Najaf Roadway consistently experiences the highest traffic loads, peaking at 5,620 veh/h, indicating its critical role in interprovincial movement. The Baghdad and Karbala Roads exhibited moderately high volumes, reflecting their function as regional connectors. 60th Street, the main internal thoroughfare, records substantial flows in both directions, reinforcing its status as a congested urban spine. In contrast, Al-Atbaaba and Al-Mahkamh Streets, which display lower traffic volumes, provide essential access to institutional and administrative zones, justifying their inclusion in strategic traffic planning. The maximum and minimum rows in the table highlight the daily variability in volume, which is crucial for modeling the LOS and identifying infrastructure bottlenecks. Overall, the data captured and summarized in Table I serve as a foundational input for simulation modeling, LOS evaluation, and subsequent economic feasibility analyses conducted later in the study.

Figure 3 portrays the variation in peak-hour traffic volumes across the eight key roads in Hilla in November 2024. The graph highlights significant daily fluctuations, with Najaf Roadway consistently showing the highest volumes, followed by 60th Street and Baghdad Roadway. This visual comparison supports traffic planning by identifying corridors with high demand and prioritizing them for future interventions.

To evaluate the impact of the proposed ring road on the traffic flow distribution, a field questionnaire was administered to determine the proportion of vehicles traveling along the (external-to-external) route—vehicles transiting between southern and northern governorates without entering the central core of Hilla. The survey, conducted during peak hours, involved 50 vehicles per major arterial road, with participants indicating their origin-destination patterns and preferred routing options. Based on the responses, traffic volumes were disaggregated into two categories: those continuing to use the external-internal path through the city and those expected to divert to the ring road.

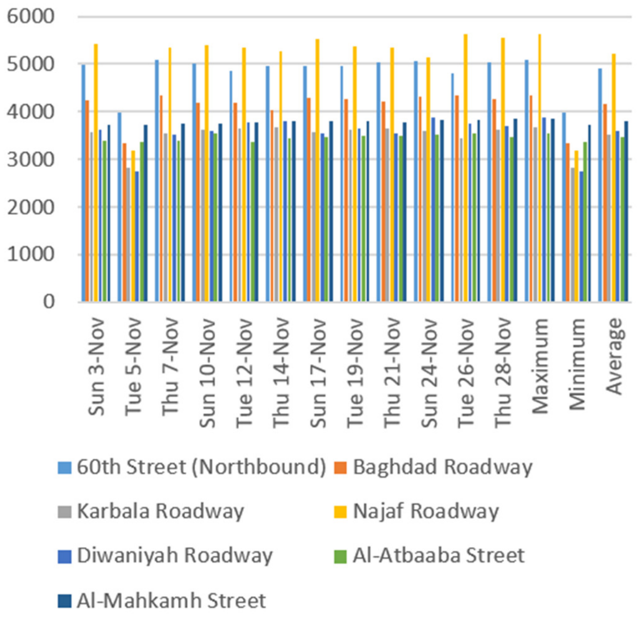

Fig. 3. Peak-hour traffic volumes for major roads in Hilla city in November 2024.

Table II presents the anticipated reductions in vehicular traffic for the key roads in Hilla following the implementation of the ring road. Reduction percentages were derived from the questionnaire findings and reflect the share of (external-external) traffic likely to bypass the city. These percentages were applied to the average observed peak-hour volumes to estimate the number of diverted vehicles and residual volumes that would remain within the urban network.

In the baseline condition, 60th Street had an average peak-hour volume of 4,899 veh/h, whereas the effective directional capacity estimated in accordance with the HCM [11] was approximately 4,250 veh/h. This produced a V/C ratio greater than 1.2 and an observed mean speed of only 15 km/h, which are characteristic of LOS F, indicating oversaturation and unstable traffic flow. Following the implementation of the proposed ring road, the diversion of external-to-external trips reduced the effective traffic volume by 32% to 3,331 veh/h. Under these conditions, the V/C ratio decreased to approximately 0.78, with the average operating speed increasing to 35–40 km/h. According to the HCM thresholds [11], such operational parameters correspond to LOS B, thus substantiating the reported improvement from LOS F to LOS B.

TABLE II. TRAFFIC VOLUME REDUCTION AFTER RING ROAD IMPLEMENTATION

Street	Traffic volume before	Reduction %	Reduction volume	Traffic volume after
60th Street (Northbound)	4899	0.32	1568	3331
60th Street (Southbound)	4592	0.38	1745	2847
Baghdad Roadway	4169	0.29	1209	2960
Karbala Roadway	3533	0.27	954	2579
Najaf Roadway	5207	0.33	1718	3489
Diwaniyah Roadway	3595	0.25	899	2696
Al-Atbaaba Street	3468	0.1	347	3121
Al-Mahkamh Street	3792	0.1	379	3413

To project post–ring-road traffic in Hilla, 2024 counts were adjusted for the diversion of external-to-external trips using rates derived from a structured peak-hour questionnaire on key arterials. The reduced volumes (post-ring road) were subsequently projected to 2035 using the Compound Annual Growth Rate (CAGR) model. Assuming a steady annual traffic growth rate of 2.5%, as established in previous regional transport studies [8, 10], future volumes were calculated using:

$$\text{Future volume} = \text{adjusted 2024 volume} \times (1 + 0.025)^{11} \quad (8)$$

The growth multiplier over 11 years was computed as approximately 1.313. This factor was applied to the adjusted 2024 volumes for each roadway segment to estimate the projected traffic volumes for 2035. Table III presents the results of these projections. It shows the original 2024 traffic volumes, the estimated percentage reductions attributed to ring road implementation, and the resulting adjusted volumes.

Consistent patterns have been observed elsewhere, such as in Hutchinson, where screening for the NE Ring Road projected approximately 1,800 vehicles/day (or about 12% trucks) under a multi-criteria framework [12], and in Erbil, where the video-based measurements on the 60-m Ring Road, with an average speed of 19 km/h and a peak hour factor of 0.97, indicated LOS of category F with high demand, and supported interventions, such as widening, access control, better pavement, and new bridges/interchanges [2].

TABLE III. PROJECTED TRAFFIC VOLUMES AFTER RING ROAD IMPLEMENTATION – YEAR 2035

Street	Traffic volume (2024)	Reduction %	Volume reduction	Adjusted volume (2024)	LOS	Projected volume (2035)	LOS
60th Street (Northbound)	4899	0.32	1568	3331	C	4372	E
60th Street (Southbound)	4592	0.38	1745	2847	B	3730	D
Baghdad Roadway	4169	0.29	1209	2960	B	3887	D
Karbala Roadway	3533	0.27	954	2579	B	3386	C
Najaf Roadway	5207	0.33	1718	3489	C	4580	F
Diwaniyah Roadway	3595	0.25	899	2696	B	3539	D
60th Street (Northbound)	4899	0.32	1568	3331	C	4372	E
60th Street (Southbound	4592	0.38	1745	2847	B	3730	D

VIII. CONCLUSIONS

This study presents a comprehensive evaluation of an 87 km ring road proposed to encircle Hilla city as a strategic intervention to mitigate urban traffic congestion and enhance inter-governorate mobility. This study integrated Geographic Information Systems (GIS)-based spatial optimization with field-based traffic data and economic feasibility analysis to assess the project's viability. The results demonstrate that the proposed ring road can significantly improve the traffic conditions in the city, with Level of Service (LOS) improvements from F to B/C, average internal speed increase from 20–25 km/h to 35–40 km/h, and a vehicular delay reduction of approximately 40%. Economically, the project is viable, exhibiting a Net Present Value (NPV) of 98.6 million USD, a Benefit-Cost Ratio (BCR) of 1.537, and a Payback Period of 9.17 years. The Effectiveness Index (EI.) of 0.48 further confirms the integrated technical and financial advantages of this intervention. These findings affirm the strategic value of the ring road in addressing mobility challenges in medium-sized urban centers and offer a replicable framework for infrastructure planning in similar contexts across Iraq and other developing regions.

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