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EVALUATING THE QUALITY OF PUBLIC TRANSPORT SERVICE IN AL-RASHEED MUNICIPALITY, BAGHDAD

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ABSTRACT

Urban mobility sustains the concept of sustainable development by using efficient modes of transport such as public transit to reduce congestion and minimize pollution. Limited research is known about the level of effectiveness of the transport system in conflict-prone cities like Baghdad, where there are limited data. In this work, the assessment of the level of service (LOS) of the transit system in the Al-Rasheed municipality has been conducted using survey and travel-time data derived from global positioning system (GPS). The study includes 13 lines (one bus line and twelve minibuses) with regard to peak and non-peak hours of operation, making a total of 26 observations. The study results show that the general LOS reduces from b to c from peak to off-peak hours of operation, while line 1 (bus line) is the poorest-performing line because of infrequent service, overcrowding, and long travel time. Stepwise linear regression identifies the transit-auto travel time difference as the single variable that determines the LOS, explaining 84.9% of the variation ($R^2 = 0.849$, $p < 0.001$). Practical recommendations include restructuring routes, increasing service frequency, and implementing real-time monitoring systems to improve reliability and passenger satisfaction.

KEYWORDS

Transit systems, GPS-based transit route mapping, Bus service, Objective service quality, Operational LOS.

1. INTRODUCTION

Sustainable urban mobility enables adjustment to the negative effects of city sprawl, traffic congestion, and air pollution in most dynamic cities. Public transport is a vital part of equitable, environmentally friendly, and efficient mobility. Level of service (LOS) is a common framework used in the literature to examine the quality of bus service, and it consists of operational elements such as headway, frequency, service hours, load factor, competitiveness, and travel time (Lucas, 2012). LOS concepts, especially those embedded in the Transit Capacity and Quality of Service Manual (Kittelson et al., 2003), are extensively developed but relatively rarely applied outside of advanced contexts, leaving a methodological gap within developing cities.

2. LITERATURE REVIEW

Newer techniques have been developed for LOS assessment in recent literature. Berrebi et al. (2021) explored the impact of service frequency on ridership elasticity. Sun et al. (2021) developed demand estimation using Bayesian modeling. Real-Time Network Design and Operational Load Prediction were explored by Benli and Akgün (2021); while these advances have been considerable, many developing cities still face operational and structural weaknesses of the transit systems that constrain them from meeting growing mobility demands (De Gruyter et al., 2016; Fan et al., 2024).

Education researchers recognized the need for large-scale performance models (Bakar et al., 2022). Using panel regression, Moovendhan et al. (2024) found that bus fares and customer ratings are positively related to performance outcomes, whereas longer travel times negatively affect them. Deb and Ahmed (2019) and Hassan et al. (2013) pointed out ongoing difficulties with measuring bus service quality and further emphasized the need for reliable and improved methods. Similarly, Hensher et al. (2003) pointed out that perceptions are subjective but indicators are objective, and this often leads to contradictory interpretations. The research by Verma and Rastogi (2022) categorized evaluation strategies into operational, perception-based, and hybrid. Recent works (Weng et al., 2023; Nesheli et al., 2017; Hawa et al., 2023) have highlighted the importance of fusing operational data with user preferences. Spatial and temporal methods provide alternative perspectives on how to assess transit. For example, Mesbah et al. (2012) used GIS visualizations to assess the tram performance in Melbourne. Orth et al. (2011) studied macro- vs. micro-level spatial-temporal indexes and tenant-based cover periods. Yin et al. (2025) developed a transferable supervised learning framework based on minimal infrastructure to facilitate real-time load forecasting prediction. Some emerging findings of transport operations and infrastructure from an Iraqi context have recently been reported. Hachim and Swadi (2024) optimized traffic signal timings to minimize waiting time. Asad and Saeed (2024) calculated truck crash risk components in Al-Najaf; finally, Al-Janabi and Obaidi (2024) evaluated pavement distress under overloading conditions in Hilla. These results are complementary to those of the present study by emphasizing the crucial role of some measures of operational efficiency and infrastructure status with a direct local effect on service quality.

3. RESEARCH GAP AND OBJECTIVES

Despite recent global methodological advancements and limited research on transit as it relates to Iraq. Prior studies in Baghdad such as Asmael and Waheed (2023) and Nasser and Qasim (2024) only focused on partial routes over non-complex LOS measurements. In none of these studies' multimodal integration, GPS-based data or regression analysis was included. To fill this gap, the current study utilizes regression-based multimodal analyses of public transportation using GPS in Al-Rasheed Municipality, Baghdad. This study integrates LOS classification, stepwise regression modeling and GIS visualization to generate an empirical basis for informing transit practice in fragmented cities towards more equitable transit provision and operations.

4. STUDY AREA

The representative study area was Al-Rasheed Municipality in Baghdad, Iraq. It is the largest district in Baghdad's municipality (southwest of the Tigris River) and serves as a major transit area between both residential and commercial areas. Spatial boundaries and internal neighborhoods are illustrated in Fig. 1 and Fig. 2, respectively.

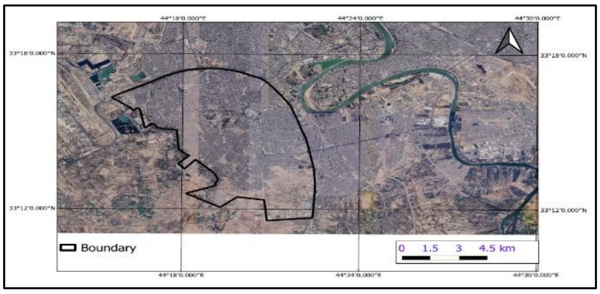


Fig.1. Satellite image of Al-Rasheed Municipality Boundary

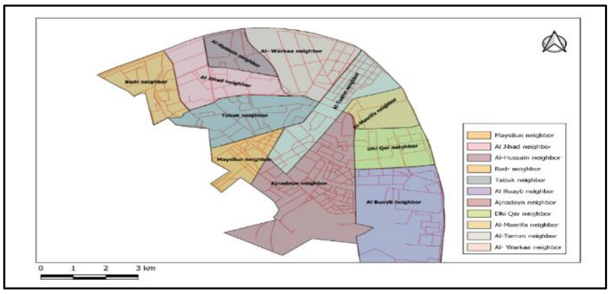


Fig.2. The Neighbourhood of Al-Rasheed Municipality (Source: Authors)

5. DATA COLLECTION

Field observations encompass manual passenger counts at selected stations, direct measures of bus frequencies, headways, and waiting times measured at regular intervals, as well as conducting interviews to analyze travel behavior and motivations behind the use of public transport. The surveys were administered on multiple occasions throughout the workday, such that peak and off-peak working hours are captured. Al-Maaini (2002) reported the demand changes of various bus services and indicated that peak hours occur in the morning (6: 00 am – 9: 00 am), and off-peak hours are seen in the afternoons (3: 00 pm – 6: 00 pm). The research indicates the peak and off-peak times of some examined bus lines in Al-Rasheed Municipality based on both survey findings and interviews with bus drivers. Therefore, we chose those periods for our study. There are 13 main lines in the public transport network within this area of interest. These routes all start from al-Bayaa neighborhood and pass through other nearby neighborhoods to construct a public transport network across the area. The direct observations were performed during four months from January 5, 2025, to May 5, 2025. The recordings were made on regular weekdays. The Baghdad Transit Authority said there are no definitive official maps of the plan available. This included using existing routes of public transit services. The Geo Tracker mobile application was used. The device allowed continuous live recording of the bus journey, along with geographical data points (actual route, stops, trip length, and weather conditions) and speeds at each instant of the travel. These can be represented in GIS (Geographic Information Systems).

6. BUS ROUTE MAPS

In the district, there are 13 public transport routes: Line 1 is operated by buses, and the remaining 12 routes are operated by minibuses only. Route geometry was recorded in the field using the Geo Tracker GPS mobile application and integrated into GIS for visualization. Figs. 4 and 5 show the mapped bus and minibus alignments; field mapping showed overlaps in certain routes (Lines 1, 2, 5, 11), as well as a blend of internal versus inter-municipal terminations leading to redundant routes in the network with operational inefficiency.

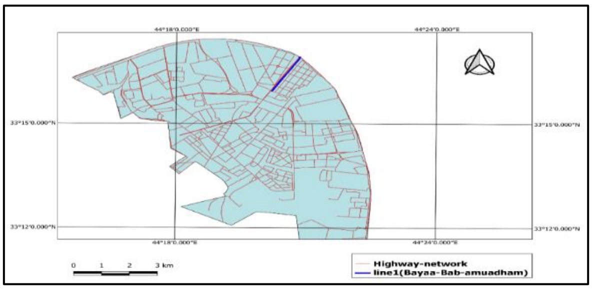


Fig.4. Bus Transit Route in The Study Area (Source: Authors)

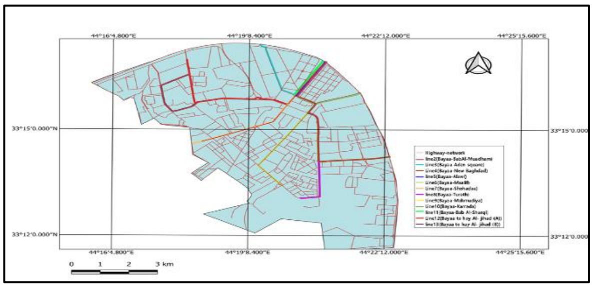


Fig.5. Minibus Transit Route in The Study Area (Source: Authors)

7. LEVEL OF TRANSIT SERVICE ASSESSMENT

This research adopts an objective, operations-driven methodology to assess the LOS for public transport. Field-based indicators, including headway, passenger load, service hours, and the transit–auto travel time difference, were systematically collected and analyzed. The Transportation Research Board (TRB) established rules for evaluating the LOS for public transportation. The definition of LOS is outlined in the Transit Cooperative Research Program

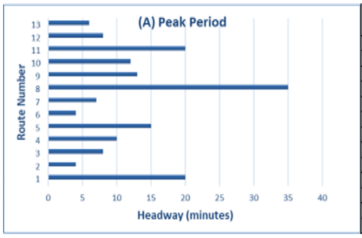
(TCRP) study (Kittelson et al., 2003). This study referenced six performance indicators, spanning from LOS A to LOS F. Fixed-route quality of service assessment is categorized into two primary dimensions: (1) availability and (2) comfort and convenience. LOS classifications for headway, service hours, passenger load factor, and travel time difference follow standards defined by Kittelson et al. (2003), as summarized in the Transit Capacity and Quality of Service Manual (TCQSM).

7.1. Evaluation of the Transit Availability

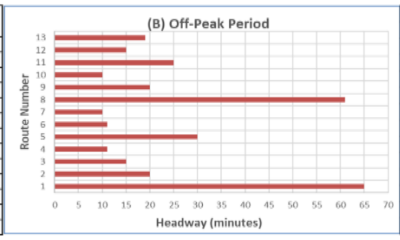
7.1.1. Frequency of Route Service

Service frequency in a bus route is one of the major determinants of total transit time in public bus transit and describes the number of buses leaving the stops in one hour. Frequency is inversely related to headway (the time between buses (Transportation Research Board, 2022). LOS categories for headway and frequency follow the standards defined by the Transit Capacity and Quality of Service Manual (Kittelson et al., 2003), where LOS A indicates high-frequency service (headway <10 minutes), and LOS F reflects very low frequency (headway >60 minutes). Fig. 6 shows headway LOS in the peak and off-peak periods. During peak hours, most of the 13 lines offer efficient service: Nine lines (e.g., lines 2, 3, 6, 7, 12, 13) achieve LOS A (headway of 5–8 minutes), supporting high-frequency operations that reduce passenger wait times.

But for line 8, the headway is at 35 min (LOS E), which does not work. Off-peak, the headway performance gets much worse. At LOS B or better, only four lines continue with these levels of service, while other lines decrease to LOS C, D, or F. Line 1 Line 1 shifts from 20 min (LOS C) compared to an off-peak time of 65 mins (LOS F). Such increases in headway reduce access and equity of transit during off-peak hours.



Line	LOS (Headway) Peak Period
1	C
2	A
3	A
4	B
5	C
6	A
7	A
8	E
9	B
10	B
11	C
12	A
13	A

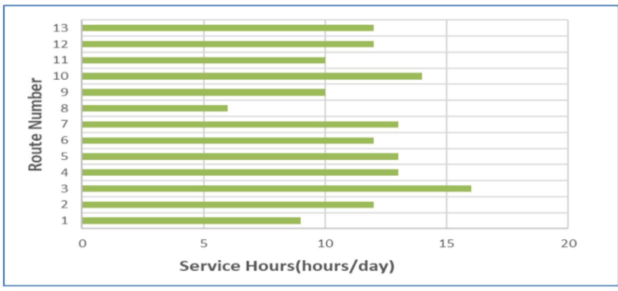


Line	LOS (Headway) Off- Peak Period
1	F
2	C
3	C
4	B
5	D
6	B
7	B
8	F
9	C
10	B
11	D
12	C
13	C

Fig.6. Fixed-Route Service Headway:(A) On Peak Period, (B) Off- Peak Period

7.1.2. Operational hours of the route service

The length of time that public transport buses run along a route every day is referred to as the hours of service. According to Kittelson et al. (2003), routes with 19–24 service hours are classified as LOS A, while those with only 4–11 hours fall into LOS E. The dataset used in this study includes 13 lines as shown in Fig. 7.A clear observation from the data is that the transit lines with the lowest hours of service values (like lines 1, 8, 9, and 11) have the lowest LOS value (grade E), while lines with the highest hours of service (like lines 3 and 10, with 16 and 14 h, respectively), reach an LOS grade C, which represents a moderate degree of service quality. This development indicates a declining LOS for high headway lines. This deterioration stem from a variety of related to Shortened hours limit the times users can access the system, with more limited operating hours for off-peak commuters, resulting in unmet mobility needs and reduced usage.



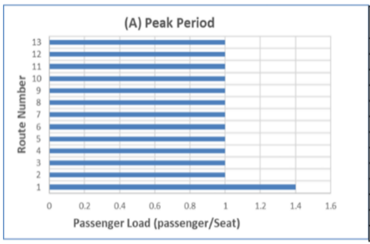
Line	LOS (Hours of Service)
1	E
2	D
3	C
4	D
5	D
6	D
7	D
8	E
9	E
10	C
11	E
12	D
13	D

Fig.7. Fixed-Route Hours of Service LOS

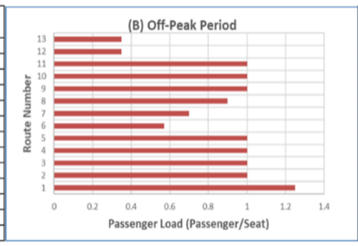
7.2. Assessment of the Level of Convenience and Ease of Use

7.2.1. Fixed-Route Passenger Load Level of Service

Travel demand LOS uses the passenger load factor to measure people per seat. A low LOS passenger load indicates extended dwell times for a specific number of people boarding and alighting at a transportation station, which makes travel times longer Passenger load thresholds defined by Kittelson et al. (2003) classify services from LOS A (very low crowding) to LOS F (crush load conditions). Fig. 8 illustrate the passenger load quality of service values for the chosen bus routes. During the peak period, Line 1 (bus operation) is defined as a heavily congested service with very high levels of crowding. This suggests that the bus capacity is insufficient to meet peak-hour demand. All minibus lines (Lines 2 to 13) were reported to have stable operation and some seating available. During the off-peak, the network recovered. Line 1 indicates reduced congestion, although service remains below an acceptable level. Minibus lines had a mixed level of service.



Line	LOS (Passenger Load) Peak Period
1	F
2	C
3	C
4	C
5	C
6	C
7	C
8	C
9	C
10	C
11	C
12	C
13	C

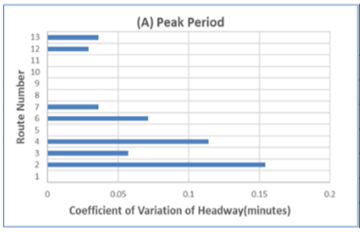


Line	LOS (Passenger Load) Off-Peak Period
1	D
2	C
3	C
4	C
5	C
6	B
7	B
8	C
9	B
10	B
11	B
12	A
13	A

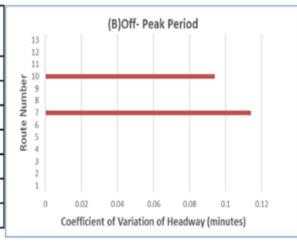
Fig.8. Fixed-Route Passenger Load LOS:(A) On Peak Period, (B) Off- Peak Period

7.2.2. Headway Adherence

Reliability is evaluated based on headway adherence for transit services operating at intervals of 10 minutes or shorter. The measure is based on the coefficient of variation of headways for transit vehicles operating on a designated route and arriving at a stop. According to Kittelson et al. (2003), headway adherence is categorized from LOS A (highly regular arrivals) to LOS F (severe bunching), based on the coefficient of variation in observed headways. In the absence of scheduled headway for the observed service, the operational headway is deduced from empirical data. Consequently, field measurements were conducted during peak and off-peak hours to calculate the average observed headway and its associated standard deviation. Service dependability was evaluated using these statistical criteria. Headway adherence was calculated using the standards set by the Transit Capacity and Quality of Service Manual (TCQSM) (Kittelson et al., 2003). Fig. 9 illustrate the results of these calculations. Signifying an extremely high level of service concerning trip travel variability. This indicates that public transport services on the investigated Lines exhibit consistent frequency with little fluctuations in vehicle arrivals, suggesting a stable operational flow.



Line	LOS (Headway Adherence) Peak Period
2	A
3	A
4	A
6	A
7	A
12	A
13	A

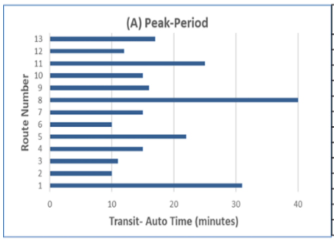


Line	LOS (Headway Adherence) Off-Peak Period
7	A
10	A

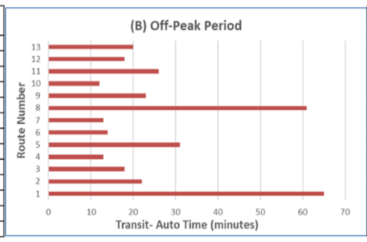
Fig.9. LOS of The Headway Adherence:(A) On Peak Period, (B) Off- Peak Period

7.2.3. Transit-Auto Travel Time LOS

One of the primary determinants influencing a potential rider's mode choice between public and private transport is the additional time burden, including waiting and transfer times, typically associated with public transportation. All travel times were recorded through direct field observations. Both public transport and car trips were conducted under comparable peak and off-peak conditions. The resulting time difference reflects the actual temporal cost incurred by transit users in the study area. According to Kittelson et al. (2003), Transit-Auto Travel Time LOS is classified from A (faster than auto) to F (over an hour longer than auto), capturing the perceived efficiency gap between modes. Fig. 10 shows service quality according to Transit-Auto Travel Time for the study. Line 1 (bus-operated) had a Transit-Auto Travel Time of 31 minutes and LOS D, indicative of inefficient service relative to auto travel by private car. In the off-peak hour, Line 1's travel time became much higher at 65 minutes and achieved LOS E, which means it was not good enough and was less efficient than private car utilization. Likewise, Line 8 (minibus) recorded a travel time of 61 minutes, corresponding to LOS F, the worst service level due to the long headway.



Line	LOS (Transit- Auto Time) Peak Period
1	D
2	B
3	B
4	B
5	C
6	B
7	B
8	D
9	C
10	D
11	C
12	B
13	C



Line	LOS (Transit- Auto Time) Off-Peak Period
1	E
2	C
3	C
4	B
5	D
6	B
7	B
8	F
9	C
10	B
11	C
12	C
13	C

Fig.10. Transit- Auto Travel Time LOS: (A) On Peak Period, (B) Off- Peak Period

7.3. Overall Level of Service Characteristics

Thirteen transit lines, one bus and twelve minibus routes were evaluated during peak and off-peak periods using quantitative indicators such as headway, frequency, service hours, load, headway adherence, and transit-auto travel time. LOS was classified per TCQSM standards (LOS A = 1, LOS F = 6) as shown in Table 1. In the peak Period, the overall LOS was B, with most minibus lines rated B or C. Line 1 (bus) underperformed (LOS D) due to overloading, inconsistent headway, and long travel times. In the off-peak period, the average LOS declined to C. Line 1 deteriorated further to LOS E, reflecting inflexible operations and low-demand inefficiency. In contrast, minibus lines 4, 6, 7, and 10 maintained LOS B, while lines 8 and 11 declined due to weak demand and poor scheduling. These results highlight the superior flexibility of minibus services, particularly off-peak. However, both service types are affected by operational and informal factors, with bus services facing challenges with structural scheduling and route adaptability.

Table 1. Overall Quality of Service

Line No.	LOS (Peak)	LOS (Off-Peak)	Line No.	LOS (Peak)	LOS (Off-Peak)
1	D	E	8	D	E
2	B	C	9	C	C
3	B	C	10	C	B
4	B	B	11	C	C
5	C	C	12	B	B
6	B	B	13	B	B
7	B	B	Overall Evaluation	B	C

7.4. Regression analysis of LOS based on operational characteristics

To this aim, a multiple linear regression analysis was performed to identify the key operational factors with an impact on the quality of public transport service. The goal of the study was to pred to this end, a multiple linear regression analysis was performed to identify the key operational factors with an impact on the quality of public transport service. The goal of the study was to predict Overall Level LOS in relation to various directly measurable variables pertaining to system operations. This covered average headway, total service hours, passenger load, the type of period (peak/off-peak), and travel time competitiveness relative to private transport. This provided 26 cases, as we calculated two sample observations, one being from peak and the other a pattern during off-peak periods, for each of the 13 public transport lines. Every observation is the mean of the following multiple field-based operational measures: headway, passenger load, service hours, and the travel time difference between transit and auto. This aggregation method keeps each route's service level while ensuring cross-line comparability. The results were then verified against the requirements for accuracy and internal consistency, allowing combined values to represent sound indicators of the real data, increasing reliability in both the dataset and results. The analysis was carried out using JASP (Version 0.18.1.0) via Enter and Stepwise methods to maintain clarity of the predictive model

7.4.1. Model Refinement – Stepwise Method

To address multicollinearity and identify the most significant predictor, a Stepwise regression was conducted. The final stepwise model retained only one statistically significant predictor: Transit-Auto Travel Time Difference, with the following equation:

$$LOS = 1.747 + 0.057 \times \text{Travel Time Difference}$$

Travel Time Difference represents the gap in total travel time between public transport and private modes. This model explained 84.9% of the variance in LOS (Adjusted $R^2 = 0.842$), indicating a strong relationship between travel time disadvantage and LOS. The result is presented in Table 2 below. The positive and statistically significant coefficient suggests that a one-minute increase in travel time disadvantage results in a 0.057-point decrease in LOS. LOS is inversely coded on a 6-point scale.

Table 2 Stepwise Regression Model

Model	Variable	B	SE	β	t	p	Tol	VIF
1	Intercept	3.015	0.172	–	17.529	< .001	–	–
2	Intercept	1.747	0.129	–	13.548	< .001	–	–
	Travel Time diff.	0.057	0.005	0.921	11.600	< .001	1.000	1.000

Note:, B= Unstandardized coefficient, SE= Standard Error, β=standardized coefficient, Tol= Tolerance, VIF= Variance Inflation Factor, a measure of multicollinearity.

7.4.2. Model Diagnostics and Validation

All key regression assumptions were met: no multicollinearity (VIF = 1.000), no autocorrelation (Durbin–Watson = 1.349), no influential outliers (Cook's Distance < 1), and residuals showed approximate normality and homoscedasticity as illustrated in Fig. 11 and Table 3. External validation was not possible due to data limits; the model is therefore internally robust for the aggregated 26 route-period observations.

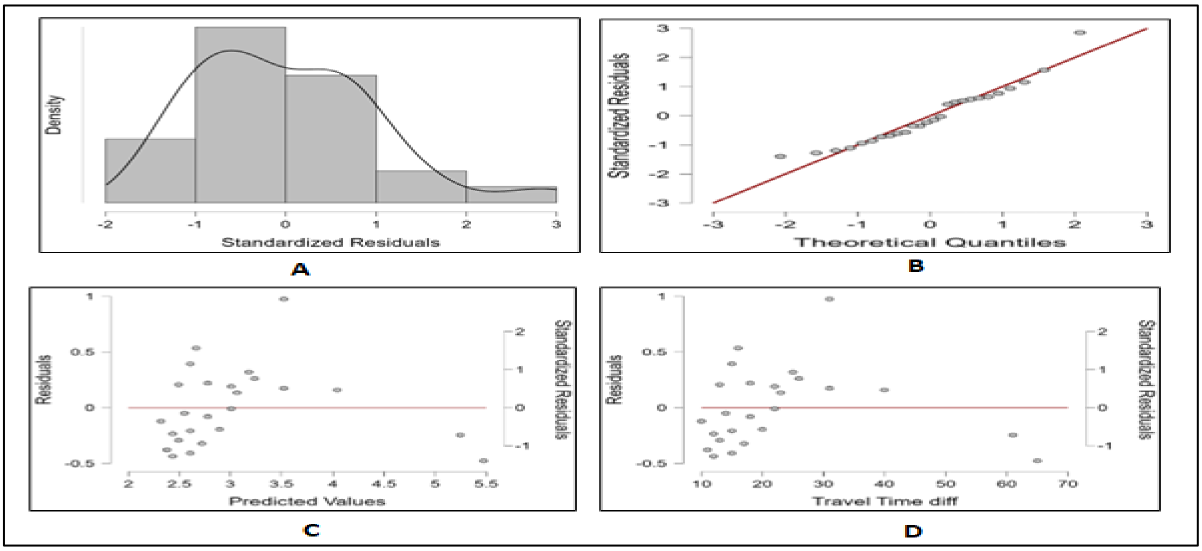


Fig.11. Diagnostic plots for regression residuals: (A) Histogram of standardized residuals, (B) Q-Q plot of standardized residuals, (C) Residuals versus predicted values, (D) Residuals versus travel time difference

Table 3 Model Diagnostics and Residual Analysis

Diagnostic Test	Result	Interpretation
R^2	0.849	Strong explanatory power
Adjusted R^2	0.842	Adjusted for model complexity
RMSE	0.348	Low average prediction error
Durbin-Watson	1.349	No autocorrelation
VIF	1.000	No multicollinearity
Cook's Distance	< 1 for all cases	No influential outliers
Std. Residuals	All < ±3	No extreme cases
Q-Q Plot of Residuals	Approximately linear	Normality assumption met
Residuals vs. Predicted	No pattern	Homoscedasticity verified

Note: R^2 = Coefficient of Determination; Adjusted R^2 = Adjusted Coefficient of Determination; RMSE = Root Mean Square Error; VIF = Variance Inflation Factor.

7.4.3. Results and Discussion

The analysis shows that the transit–auto travel time difference is the sole significant operational predictor of service quality, explaining 84.9% of the variance. This shows that system behavior fundamentally governed by temporal competitiveness to private modes , a result consistent with Deb and Ahmed (2019) and Moovendhan et al. (2024). Parallel operational studies similarly show high travel time ratios and unreliability constrain efficiency, restricting ridership growth (Yun et al., 2024; Zhang et al., 2024). Limitations include GPS inaccuracies, observer bias in field surveys and a lack of disaggregation between time components (e.g., waiting, transfer, in-vehicle). Future work could utilize automated datasets and incorporate travel time reliability metrics that enhance operational evaluation.

8. CONCLUSIONS

In this study, the performance of public transportation in Al-Rasheed municipality (Baghdad) has been analyzed using level of service (LOS) indicators estimated via regression analysis. The results show a drop in average performance from LOS B in peak hours to LOS C in off-peak hours, and temporal inconsistency is also found. concerning the buses, line 1 was found to perform the worst because long headways and low efficiency; however, many minibus lines (4, 6, 7, 12, 13) were operating at LOS B. according to the regression analysis, only one indicator showed a significant effect on LOS (transit-auto travel time difference, R2 = 0.849, p < 0.001); 84.9% of the variance in LOS was explained by this indicator. Thus, it can be seen that the use of operational data with GPS technology can serve as an effective way of analyzing urban public transport when there is a lack of data available. Improving the system at Baghdad must involve implementing practical measures including reducing headways, increasing system frequency, introducing ITS solutions and restructuring overlapping routes in cases where overlapping routes to enhance efficiency and user satisfaction.

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