

Research Article

Assessing the Operational Efficiency of Public Transport in Rajshahi: A User and Operator Perspective

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Abstract

Sustainable development is a broad concept stems from environmental, social and economic equality and vitality. A well-functioning Public transport system is also an important part of a sustainable transportation system, as it focuses on reducing traffic congestion, pollution and provides affordable mobility facilities for people. So, performance evaluation of this public transportation system is a fundamental requirement for a rapidly growing metropolitan city like Rajshahi. Rajshahi is the fourth largest divisional city, containing both motorized and non-motorized transport facilities. The aim of this study is to evaluate the performance of Rajshahi's public transport system based on efficiency measurement. The main mode of transportation system auto rickshaw, has been selected for this study. Service efficiency, cost efficiency, system efficiency, utilization efficiency and network efficiency are being assessed from both passenger and operators' perspectives. For the purpose of this investigation, Railgate is considered as the center point, and the Railgate to Binodpur, Railgate to Bazar, Railgate to Court station and Railgate to Nowhata routes are selected. The data collection process was done by conducting questionnaire surveys of passengers and drivers. Also, other data such as velocity, distance, time of travel and delay time were measured by direct observation. The study result reveals that network efficiency is the highest, securing 73.50%, while system efficiency is the lowest, at around 18.48%. Additionally, service efficiency, cost efficiency and utilization efficiency are 37.21%, 22.71% and 30.95%, respectively. These values indicate that although the vehicle speed is faster, the number of auto-rickshaws is increasing in a considerable amount lead to traffic congestion delay. The study outcomes provide an overview of the Rajshahi city transport system, contributing valuable insights for the development of a long-term and well-planned transportation system.

Keywords

Transportation System, Public Transport, Performance Evaluation, Efficiency, Rajshahi

1. Introduction

Urbanization is redefining cities across the globe, placing greater strain on urban structures and transportation systems. Particularly, developing cities are experiencing an increasing pressure with populations and economic activity overwhelming transport networks. Rapid urban expansion in low- and middle-income countries has been strongly associated with increased

travel demand, spatial mismatches between housing and employment, and rising dependence on road-based transport systems [1]. Achieving sustainable, equitable, and environmentally responsible urban mobility requires efficient public transport (PT) systems, as identified in research on global urban development and the Sustainable Development Goals. The efficiency of urban public

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transport has been central to accessibility, traffic congestion, emissions, and the general quality of life in fast-growing cities. As an example, the recent literature underscores the fact that the performance of urban transport needs to be measured along a variety of dimensions, including service reliability, cost-efficiency, network coverage, and vehicle utilization, to allow sustainable planning of mobility [2, 3]. Rajshahi is a major urban, commercial, and educational center in Bangladesh, covering an area of 96.72 km². The city's urbanization rate stands at 32.93%, indicating that the city's population has continued to grow over the past few years. This development demonstrates the growing importance and the enlarging urban impact of the city. The population increased by 1.52% and 1.48% in the years 2017 and 2019, respectively, indicating a consistent population growth. The population increase rate will be estimated at 2.43% in the year 2030, which highlights the fact that the city is constantly developing into a more dynamic and densely populated urbanized space [4, 5]. The city is a fast-urbanizing city and its population is growing at a good rate, as well as the demand for vehicles. According to RCC sources, the number of auto-rickshaws that are running in the city is 30,000 and above, 10,000 and above, which, according to RCC authorities, had gained licenses of 20,000 auto-rickshaws and 1500 auto-rickshaws, respectively [6]. Lower and lower-middle classes, such as people who drive auto-rickshaws, do it because it is fast and cheap. It is also an easy way to earn some cash, and not difficult enough to do [7]. These modes provide critical mobility services but often operate with minimal regulation, contributing to traffic congestion and operational inefficiencies at the network level [8]. Nonetheless, this fast urbanization and the growth of reliance on informal

means of transport have brought with them a number of issues to the general transport management in the city. The transportation system in the city is complex due to poor infrastructure, policies, and traffic composition, whereby there is over-saturation of non-motorized transport, absence of a dependable transport system, and ineffective traffic management practices. The transport system suffers from ineffectiveness and inefficiency in the efficiency of the traffic system in Rajshahi city due to congestion at major crossroads, markets, and CBDs [9].

Although several studies have assessed public transport conditions in Bangladesh, most focus on large metropolitan cities such as Dhaka and Chattogram. Studies specifically investigating operational efficiency in medium-sized cities such as Rajshahi are scarce. Moreover, the current research seldom considers informal or semi-formal transport options (i.e., battery-operated auto-rickshaws) within a multi-dimensional efficiency framework. International literature emphasizes evaluating public transport using indicators such as service reliability, cost efficiency, vehicle utilization, and network performance [8, 10, 11]; however, there is no comprehensive study applying these indicators to Rajshahi's auto-rickshaw system. This creates a significant knowledge gap at a time when the mode is expanding rapidly and shaping the city's mobility landscape.

The objective of this study is to find the overall efficiency of the public transport system in Rajshahi city, including service efficiency, cost efficiency, system efficiency, utilization efficiency and network efficiency. Also aims to provide route-wise service, utilization and network efficiency of this city, considering off days and working days.

2. Methodology

2.1. Study Area

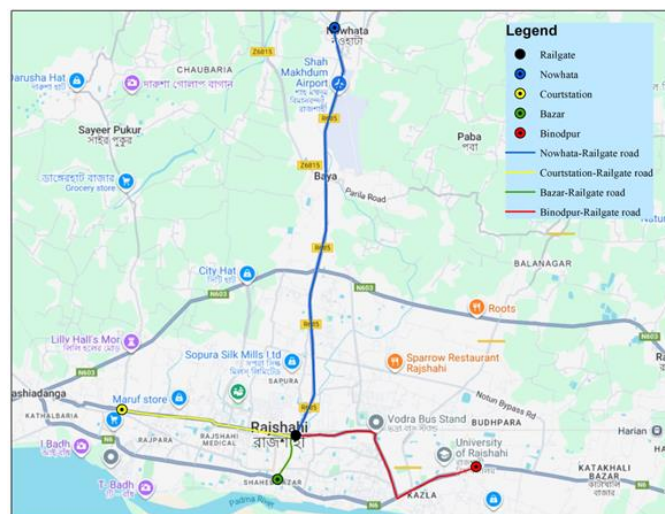


Figure 1. Study Area.

The research was carried out in Rajshahi City, a big city in the northwestern area of Bangladesh, situated on the bank of the Padma River. The city is characterized by the rising number of people, the number of education facilities, and the rising number of people who want to use public transport. The public transport system in Rajshahi mainly comprises minibuses, human-haulers, rickshaws, and recently added battery-powered auto-rickshaws, which are used in making short and medium-range journeys around the city. In order to measure the efficiency of the operation of the public transport, four key routes stemming out of the central transport hub at Railgate have been chosen. These routes have been selected on the basis of high traffic, their connection to important areas of commercial and institutional interests and the diversity of traffic and road conditions in the city.

2.2. Selected Routes

The Railgate Binodpur route is a route that links the central railway location to the Binodpur intersection, which is also close to the University of Rajshahi. The road has a high population of students and commuters who do their daily journeys, and thus, this is a critical transportation route within the region. It has a moderate flow of traffic and a length of about 5.2 km that allows it to pass through several educational and residential areas, which implies that students and residents use it heavily.

The Railgate Court Station route is a southbound road to the central business and administrative district of Rajshahi, which stops around the court area. With a rough estimated length of 4.1 km, this route has a high number of people using it and has frequent stoppages, which may delay people, especially in peak hours. The road also has a combination of both motorized and non-motorized transportation, which adds to the difficulty in the traffic flow and further increases the congestion.

The route that runs through Railgate to Nowhata is one of the busiest intersections in Rajshahi that links different areas of the city. This route is approximately 8.9 km long; it is commercially congested and has a large flow of passengers during the day. The route is also characterized by mixed traffic, whereby there is a mixture of motorized and non-motorized vehicles, which makes it heavily used and congested at peak hours.

The Railgate Shaheb Bazar route is one of the most active in Rajshahi, linking the railway area to the main shopping and trading hub of the city. Spanning approximately 1.1 km, this route is characterized by narrow roads that often experience frequent congestion, especially during peak hours. Additionally, the area sees high pedestrian movement, further contributing to the traffic challenges and making it a bustling corridor for both vehicles and foot traffic.

A base map of Rajshahi City was used to identify and visualize these routes. The route lengths were measured using GIS tools (ArcGIS), ensuring accuracy in spatial data representation.

2.3. Approach

A two-way (field surveying and direct observation) study was used to determine the operational efficiency of the public transport in the City of Rajshahi. The field survey was a structured questionnaire, which was administered to daily commuters along the chosen routes, as a means of collecting first-hand data on the travel patterns, satisfaction of the customers with the service, frequency of the service, punctuality, comfort, and safety. At the same time, direct observation was made in each route in order to document the actual operational performance in terms of vehicle velocity, passenger load, waiting time and the travel time.

By integrating these two methods, the study ensured both empirical accuracy and contextual understanding of how public transport systems function under real urban conditions in Rajshahi [12].

2.4. Data Collection

Data for this study were collected through questionnaires and interviews with both passengers and auto-rickshaw drivers/operators. Passengers were surveyed to assess their satisfaction with service efficiency, comfort, fare levels, and availability of auto-rickshaws along the selected routes. Interviews with drivers/operators focused on understanding their income levels, operational challenges, and perspectives on service efficiency. The data gathered from both groups provided valuable insights into the performance of the public transport system in Rajshahi.

Table 1. Questionnaires for passengers and drivers.

Questions for the Passengers	Questions for the Drivers
What is the Age of the passenger?	Age
Job description	Monthly expenditure on vehicles
Monthly Transportation cost	Monthly income
Monthly income	Service Route

Questions for the Passengers	Questions for the Drivers
Routes you usually travel	Time of service on those routes
No. of trips daily on this route	Daily service time
Daily cost on this route	

2.5. Sample Size

A total of (18 ± 2) passengers and (15 ± 1) drivers were surveyed on each route. Although the sample size is modest, similar exploratory urban transport studies in Bangladesh have used comparable sample sizes for route-level efficiency assessment [12]. Given the homogeneous nature of auto-rickshaw operation and short route lengths, this sample size provides a reasonable representation for analysis.

2.6. Efficiency

2.6.1. Service Efficiency

Service efficiency of a public transport system is described as the ability of the system to satisfy the needs and expectations of the system users efficiently in relation to the different operational and user-friendly elements of the system. It is normally assessed in terms of waiting time, comfort, reliability, frequency, and accessibility. Less waiting time and increased service frequency are also convenient and minimize the frustration of the passengers. Cleanliness, seating, and comfort in general add to the experience of the passengers. Previous research described the use of weighted delay and schedule reliability indexes for this purpose [13]. In this study, the weighted delay index was established by comparing transit-trip delays with the number of late trips resulting from transit service disruptions. The equation,

$$\text{Weighted Delay Index, } R = \sum_{k=1}^H \frac{k \cdot p(k)}{H} \quad (1)$$

where H is the scheduled headway, k is the universal delay (in minutes) ($0 < k \leq H$), and $p(k)$ is the probability of delay k observed. R should take values between 0 and 1, where a higher value means lower dependability.

2.6.2. Cost Efficiency

Cost efficiency in the case of public transport refers to the economic aspect of the system in terms of its economy, while delivering satisfactorily to the passengers. It can be measured in terms of fare structure, sufficiency of revenue, and cost of maintenance and day-to-day running. Fare structure must be made to be affordable to the users and be capable of creating

sufficient revenue to keep the service going. Revenue adequacy is used to show that the revenue obtained through fares and other means will be enough to cover operations and maintenance. Maintenance and operating costs indicate the number of resources used and the financial control of the system. Calculating the profitability index is one of the most used cost-efficiency measurement tools. This allows us to assess the operational costs and how effectively the system returns on investment.

$$\text{Profitability} = \frac{\text{Total revenue}}{\text{Total operating cost}} \quad (2)$$

2.6.3. System Efficiency

The public transport system efficiency is the capacity of the entire network to perform well in regard to vehicle performance, service coverage, and time. It may be evaluated in terms of the quality of the vehicles, services, and their working hours. The state of the vehicles is an indicator of the level of maintenance, safety, and comfort that the vehicles offer to the passengers. Service coverage is used to show the extent to which the transport network is connected to various parts of the city as well as making these areas accessible both central and peripheral. The hours of operation define the period to which the transport services can be availed to people, a factor that affects the ease and flexibility of day-to-day commuters.

For this research, system efficiency was calculated by appraising the travel time, walking distance and time, waiting time to board the auto rickshaw, and travel cost. The transportation affordability index is used to measure system efficiency. In this study, transportation affordability is defined as the percentage of income spent on travel purposes. The equation we used here,

$$\text{Affordability Index} = \sum_{i=1}^n \frac{X_i \times P}{y} \quad (3)$$

Where X_i is the number of trips per month, P is the expense per trip, and y is the monthly income.

2.6.4. Utilization Efficiency

Utilization efficiency in public transport measures how effectively the available resources, such as vehicles and routes, are being used to serve passengers. It is commonly analyzed through occupancy rate and trip frequency. The occupancy rate reflects the proportion of seats filled during operation, indicating whether the service matches passenger demand. A

higher occupancy rate generally means better use of capacity and reduced wastage of resources. Trip frequency refers to how often vehicles operate on a particular route within a specific period, showing how efficiently the system meets travel needs throughout the day. Average vehicle utilization, passenger per vehicle per day (PPVPD), passenger-kilometers, and vehicle availability were measured to measure how the system is utilizing available resources for measuring utilization efficiency. Vehicle utilization efficiency was calculated using the ratio of average working hours to total working hours.

$$\text{Average vehicle utilization (\%)} = \frac{\text{Average working hours}}{\text{Daily working hours}} \quad (4)$$

Passenger per vehicle per day (PPVPD) is defined as the number of passengers transported by a vehicle divided by the total number of vehicles and operational days [14]. It is influenced by the vehicle capacity, average occupancy, route length, number of trips, average distance traveled by the passenger, headways, and average travel time.

$$\text{PPVPD} = \frac{\text{Total number of passengers carried}}{\text{Total fleet size} \times \text{No of days of operations}} \quad (5)$$

2.6.5. Network Efficiency

Network efficiency in public transport refers to how effectively the transport routes and systems are organized and interconnected to facilitate smooth passenger movement. It is primarily assessed through route connectivity and integration with other modes. A highly efficient transport network provides continuous, well-connected, and multimodal mobility options, reducing travel time and improving accessibility for urban commuters. The distance between stops (segments) and

average network speed were used to measure the existing system's network efficiency.

$$\text{Average networking speed} = \frac{\sum_{i=1}^k V_i \times S_i}{\sum_{i=1}^k V_i} \quad (6)$$

3. Results and Discussion

3.1. Service Efficiency

Figure 2 shows the Figure of the Weighted Delay Index (WDI) of four major routes between various parts of the Rajshahi City and Railgate on Friday, Saturday, and Monday. The findings indicate that Friday has a lower average WDI value, which means that its work and operations are less complicated and have fewer delays because of the lower level of traffic congestion and passenger demands. With Friday being an off day, the traffic congestion is reduced and hence the delay time of the vehicle is reduced. Conversely, the values of higher WDI are registered on Saturday and Monday, indicating that the efficiency of the service declines on working days when the volume of traffic between generations rises and so does the road occupancy. The route with the largest delay indices (approximately 0.52) is Binodpur-Railgate, which means that the schedule is often delayed and the route is congested, and the delay indices of other routes are relatively lower (around 0.35), which indicates a higher service reliability. These results suggest that the patterns of traffic and passenger flow are the factors affecting the efficiency of the public transport system in Rajshahi greatly, and the route-specific and day-specific management strategies are necessary to enhance the reliability of operation in the peak times.

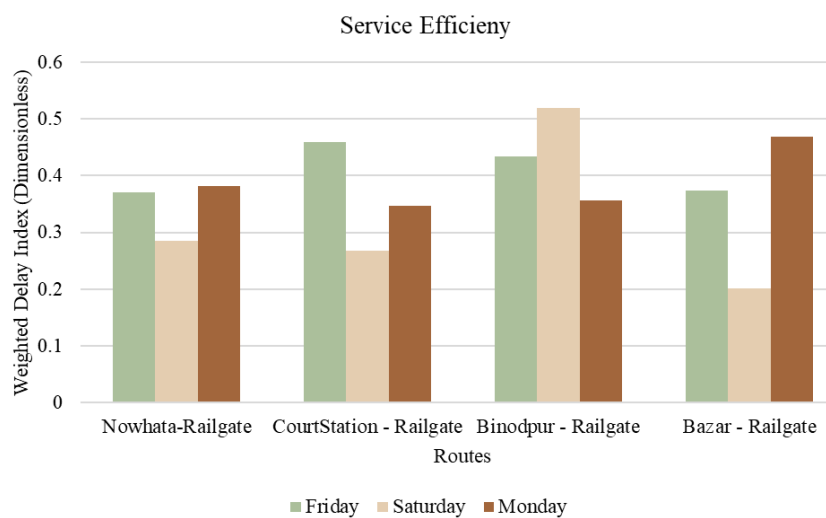


Figure 2. Service Efficiency.

3.2. Utilization Efficiency

Figure 3 shows the efficiency of vehicle utilization of the auto-rickshaws in terms of Passengers per Vehicle per Day (PPVPD). The PPVPD is the mean number of passengers that each auto-rickshaw can transport in one day and it provides the magnitude of the demand and the use of the service. As can be seen, the PPVPDs are below 200 in all routes and this indicates that the services of the auto-rickshaw are not fully utilized, meaning that the number of passengers is relatively low and the number of vehicles supplied is relatively high. The most common route includes Saturday as having the most

PPVPD, particularly in Binodpur-Railgate and Bazar-Railgate routes. This is explained by the fact that the Bazar is not open on Friday and Saturday is a working day, which contributes to the rise in the number of people and shopping on Saturday. On the other hand, Nowhata-Railgate and Court Station-Railgate exhibit relatively greater use on Monday and Friday, which is also in tandem with the regular workday commute. On the whole, the obtained results suggest that despite the peak usage of the auto-rickshaw services attended on the definite routes and days, there is low passenger load, which is a sign of underutilization and potential oversaturation of the number of vehicles in the system.

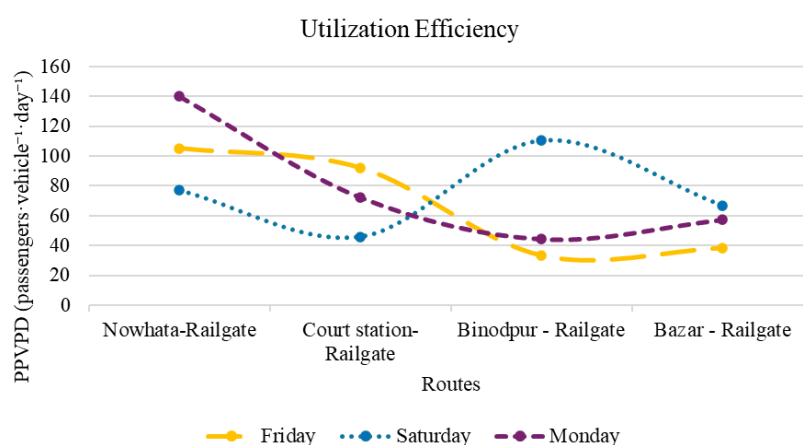


Figure 3. Utilization Efficiency.

3.3. Network Efficiency

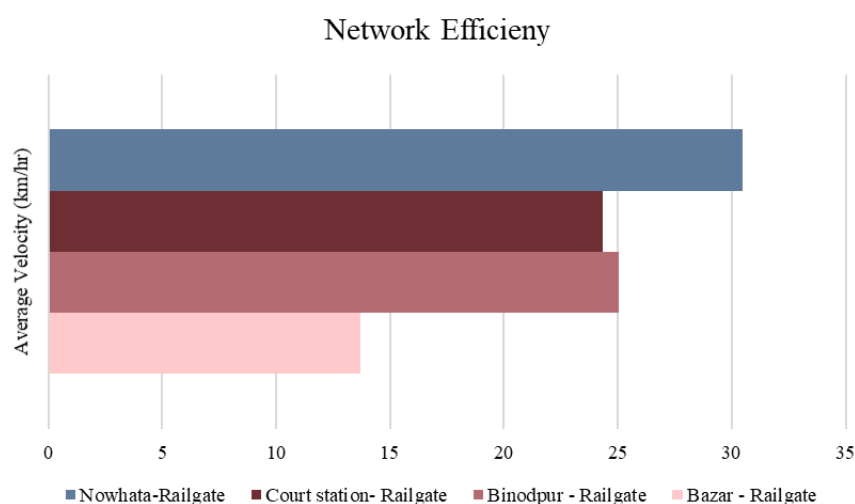


Figure 4. Network Efficiency.

Figure 3 indicates the efficiency of the auto-rickshaw services in terms of the average velocity (km/h) in four major routes, which are Nowhata-Railgate, Court Station-Railgate, Binodpur-Railgate and Bazar-Railgate. The mean speed is a

measure of the functionality of the transport network and the general effectiveness of the transport network, where higher mean speeds portray a smooth traffic flow and minimal delays. The Nowhata-Railgate route has the highest average velocity,

which indicates that it is the most efficient route with comparatively low congestion and good condition of the road. The study indicates an average speed of 40km/h and 40km/h respectively on Court Station-Railgate and Binodpur-Railgate, which means that there is moderate interference of traffic and stop times. On the other hand, route Bazar-Railgate is the one that has the least average velocity, which means that there is more congestion and regular stoppage, probably because pedestrians and commercial vehicle traffic are more common in the market locations. All in all, the value shows that network efficiency differs markedly on a route, with central market routes experiencing slower speeds as a result of heavy traffic, whereas peripheral routes like Nowhata-Railgate experience better performance in terms of operational efficiency and smooth traffic flow.

3.4. Overall Efficiency

The radar chart shows the analysis of transportation efficiency in the case of auto-rickshaw services in Rajshahi that is determined with the help of five main indicators: Service Efficiency, System Efficiency, Cost Efficiency, Network Efficiency, and Utilization Efficiency.

The Service Efficiency was 37.21, which shows a moderate frequency of the services. This implies that though the services offered by the auto-rickshaws are usually constant, passengers continue to record a certain level of waiting periods at some time of the day. Passenger comfort and satisfaction might be improved by adding to the scheduling and the regularity of services. System Efficiency had the lowest score of 18.48, meaning that the existing transport system is not very affordable to the passengers. This could be indicative of high fares in comparison to income or low access to cheap substitutes, which might diminish the general availability of auto-rickshaw services to lower-income clients.

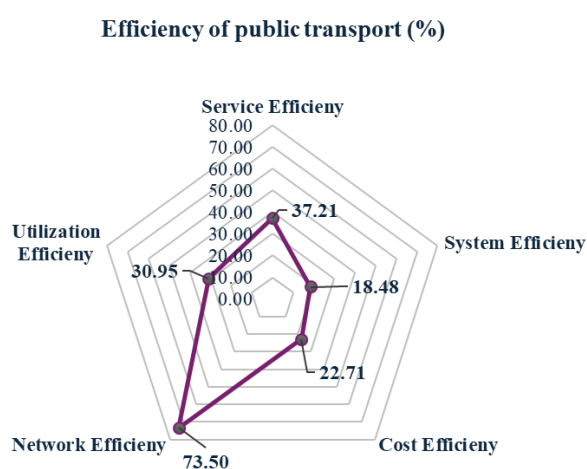


Figure 5. Overall Efficiency of Public Transport.

The Cost Efficiency was rated at 22.71, implying that the profitability of vehicle owners is quite low. This could be

because of the high price of fuel, or expensive maintenance, or poor fare collection schemes, which restrict the economic viability of the operations in the longrun. The highest score of 73.50 was attained in Network Efficiency, indicating that the services of the auto-rickshaw in terms of their speed and connectivity are quite satisfactory. This shows that the vehicles are able to move effectively in the city and offer speedy and convenient movement of the passengers in various regions. The value of Utilization Efficiency was 30.95, indicating moderate values of daily vehicle use. It implies that some auto-rickshaws may not be utilized fully or irregularly distributed during the day, despite the number being large.

4. Conclusions

The main aim of this research was to review the effectiveness of the entire public transport system in the city of Rajshahi, especially in service effectiveness, cost effectiveness, system effectiveness, utilization effectiveness, and network effectiveness. The results indicate that even though the public transport system currently shows medium efficiency in service and network, there are still serious opportunities to improve it, particularly in system and cost efficiency. The paper has emphasized how operational efficiency can differ depending on different routes, and there are unique differences in the service and utilization efficiency between working and off days. Routes to denser locations like the Railgate to Binodpur and the Railgate to Court Station experienced a greater degree of congestion and delays, and this affected the overall performance of services. Conversely, other routes, such as Railgate to Nowhata and Railgate to Shaheb Bazar, showed greater efficiency in the network, but they were not optimally utilized because of the surplus of vehicles and underutilization during the non-peak times. The findings highlight the necessity of utilizing route-specific management practices, enhanced scheduling and enhanced fare control to help the overall operation and sustainability of the city's public transport.

Abbreviations

PT	Public Transit
RCC	Rajshahi City Corporation
CBD	Central Business District
GIS	Geographical Information System
WDI	Weighted Delay Index
PPVPD	Passengers per Vehicle Per Day

Data Availability Statement

The data available from the corresponding author can be provided for verification purposes. This publication has also included references to the data that support the findings of this investigation.

Conflicts of Interest

The authors declare no conflicts of interest.

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Biography



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