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Research on the Improvement of the Efficiency of Beijing Bus Lanes Based on Data Research and Copilot for Power BI Analysis

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Abstract: This research focuses on the operational efficiency of bus lanes in Beijing, using the morning commuting time of a high school student in Haidian Distrct, Beijing, as the time series analysis sample. It comprehensively employs time series analysis and on-site investigation methods to monitor and analyze the commuting data and traffic flow in core areas such as North Third Ring Road and Zhongguancun Avenue in Haidian District. At the same time, it uses questionnaire research methods, designs multi-dimensional questionnaires, and widely collects citizens' opinions and suggestions on the operational efficiency of Beijing's bus lanes. With the assistance of the Copilot for Power BI intelligent tool for questionnaire analysis, it explores the problems existing in the setting and use of bus lanes and their coordination with non-bus lanes, and proposes targeted optimization strategies. The aim is to improve the utilization rate of bus lane resources, alleviate urban traffic pressure, and provide new thinking directions and practical references for the improvement of Beijing's traffic.

Keywords: Bus Lanes, Efficiency Improvement, Data Analysis, Copilot for Power BI

1. Introduction

Public transportation is an essential component of urban transportation systems, playing an irreplaceable role in enhancing urban transportation efficiency, reducing private vehicle trips, and lowering energy consumption and environmental pollution. As a core measure to ensure the priority of public transportation, bus lanes, by creating fast and punctual operation channels, have become a key factor in attracting citizens to choose green travel [1].

Beijing, a megacity with a population of over 20 million, has been firmly implementing the strategy of giving priority to public transportation since the opening of its first bus lane in 1997. With an average construction speed of 30 to 40 kilometers per year, the mileage of bus lanes has now exceeded 1,000 lane-kilometers. However, the rapid growth of private car ownership has made the contradiction between urban transportation supply and demand increasingly acute. During peak hours, it is common to see non-bus lanes clogged with traffic while bus lanes remain sparsely populated. This misallocation of resources not only wastes road resources but also weakens the attractiveness and competitiveness of public transportation [2]. Therefore, it has become an urgent

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task to deeply analyze the efficiency of bus lanes and explore optimization and improvement paths to solve Beijing's traffic problems and promote sustainable urban transportation development. This is precisely the starting point and core value of this study.

2. Data research and analysis

2.1. Time series analysis

The planning and construction of bus lanes in Beijing aim to enhance the operational efficiency of buses, increase the attractiveness of public transportation, and alleviate the traffic pressure, especially the congestion problem during the rush hour. The traffic pressure during the morning peak is not only due to the high overlap of commuting and school travels, but also significantly influenced by weather conditions. To explore the intrinsic relationship between travel time during peak hours and weather conditions, this study conducts an in-depth analysis using the time series analysis [3].

The time series analysis is a statistical method that takes the sequence of observations arranged in chronological order as the research object and realizes prediction and analysis by mining the inherent laws of the data. Based on the trend and seasonality of the data, methods such of moving averages and exponential smoothing are used to extract change patterns from historical data. This method is widely applied in economic indicator prediction, enterprise sales estimation, weather forecasting, traffic flow analysis etc.

This study selects the morning commuting time of a high school student in Haidian District of Beijing as the time series analysis sample [4]. It continuously records the commuting data of this student on a fixed route (from a certain residential area in Haidian District to a certain middle school in Haidian District) during morning 7:20-7:50 from September to January of 2024 autumn semester. The data collection covered commuting time, real-time weather and the traffic conditions of the bus and non-bus lanes. After screening and excluding non-standard data such as statutory holidays, 90 valid samples were obtained, including 37 sunny days and 53 days with other weather conditions such as cloudy, rainy etc. (Figure 1)

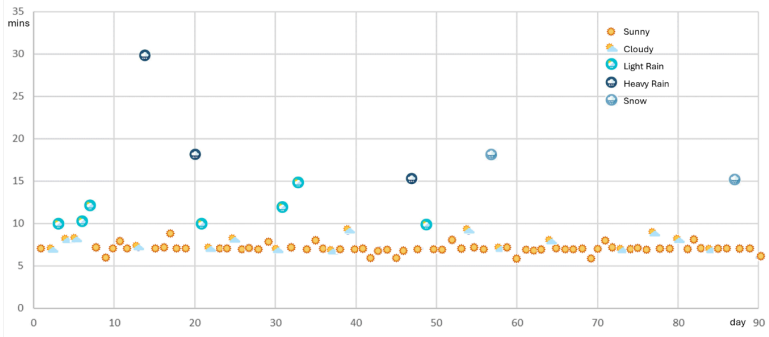

Figure 1. Distribution of daily commuting time and weather

Analysis of the 90-day valid sample data reveals that the impact of weather factors on the commuting time during the morning rush hour shows significant and differentiated characteristics. Under cloudy, overcast and smoggy weather conditions, the commuting time is basically similar to that on sunny days, with an average fluctuation range of around 5% [5]. However, the impact of rainy and snowy weather on commuting efficiency is extremely obvious: light rain increases the commuting time by 59.4%, light snow, moderate rain and sleet have more prominent effects, causing

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the commuting time to increase by 111.8%, 133.0% and 154.2% respectively, and extreme heavy rain even increases the commuting time by 323.7% [6].

By drawing a scatter plot of commuting duration and weather conditions, the relationship between the two is presented more intuitively. The data fitting results show that the relationship between the two is approximately an exponential growth trend, with a R-squared value as high as 0.9156, indicating a very strong positive correlation between commuting duration and weather conditions. (Figure 2)

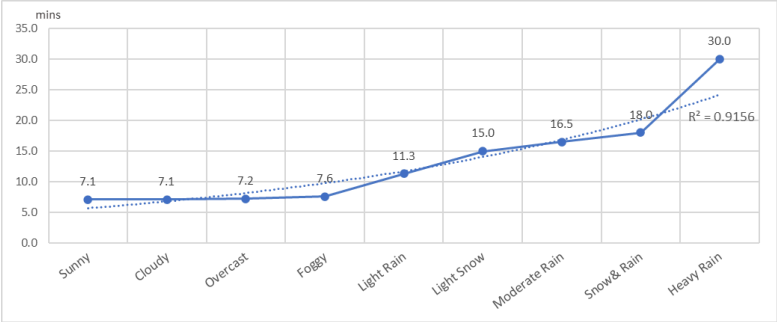

Figure 2. Average commute time

The study found that during the morning rush hour on working days, the commuting duration of private cars is closely related to weather conditions. Especially in rainy and snowy weather, factors such as slippery roads and reduced visibility lead to increased traffic congestion. The greater the rainfall, the higher the congestion level, and the commuting time also significantly increases accordingly. In sharp contrast, even in rainy and snowy weather with extremely high traffic pressure, the traffic flow in adjacent bus lanes remains at a relatively low level, and the traffic efficiency has not been fully utilized. This contrast is particularly significant in rainy weather, highlighting the idle problem of bus lane resources in adverse weather conditions.

2.2. On-site observation and sampling survey

Bus lanes, as a key facility for enhancing the service level of public transportation, the on-site observation of their traffic efficiency is an important basis for evaluating the rationality of the planning. Zhongguancun Avenue, as a north-south traffic artery in Haidian District, Beijing, has a total length of 7.2 kilometers, starting from the North Fifth Ring Road in the north and ending at Xizhimenwai Avenue in the south. It adopts a two-way eight-lane design and is an important link connecting the Zhongguancun Science and Technology Park and the core urban area. On both sides of the road, the outermost lane on each side is set as a bus lane.

As the core science and technology corridor of Haidian District, Zhongguancun Avenue has a high concentration of traffic demand during the morning rush hour (7:00-9:00) on weekdays. To deeply explore the differences in traffic efficiency between bus lanes and non-bus lanes during the peak hours, this study selects Zhongguancun Avenue (from Haidian South Road to North Third Ring Road) as the core observation object. This section not only carries a large number of commuting flows but also has a distinct contrast in traffic flow characteristics between the bus lane and the non-bus lane.

The observation point was selected at a certain intersection where traffic signals were installed. This intersection has eight lanes in both the north-south direction and each direction has one lane designated as a bus lane. In the east-west direction, there are two non-bus lanes. This observation

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point has a dense bus route network, gathering 12 regular bus routes including Route 332, 584, 614 etc., as well as one rapid bus route. This forms a rich and complex bus operation network, providing a typical scenario for observing the efficiency of bus lanes.

In terms of data collection methods, this study adopted the manual observation and counting recording method and sampling survey method. During a certain working day of the morning rush hour from 7:00 to 9:00, two observers worked collaboratively for 120 minutes to accurately count the buses and non-bus vehicles passing through this intersection. One observer was located on the east side of the signal light in the south direction of the intersection, responsible for recording the number of vehicles traveling from south to north and eastward; the other observer was located on the west side of the signal light, recording the number of vehicles traveling from north to south, eastward, as well as from east to north and south. (Table 1)

Table 1. Number of vehicles passing through

	Non-Bus	Bus		Non-Bus	Bus
South -> North / East	45	2	North -> South/East, East -> South/North	57	2
South -> North / East	42	3	North -> South/East, East -> South/North	61	0
South -> North / East	56	1	North -> South/East, East -> South/North	64	3
South -> North / East	62	2	North -> South/East, East -> South/North	45	1
South -> North / East	48	2	North -> South/East, East -> South/North	68	4
South -> North / East	50	4	North -> South/East, East -> South/North	65	2
South -> North / East	53	1	North -> South/East, East -> South/North	73	3
South -> North / East	50	2	North -> South/East, East -> South/North	62	0
South -> North / East	61	2	North -> South/East, East -> South/North	76	4
South -> North / East	59	3	North -> South/East, East -> South/North	86	3
South -> North / East	72	2	North -> South/East, East -> South/North	48	1
South -> North / East	58	5	North -> South/East, East -> South/North	69	2
South -> North / East	49	2	North -> South/East, East -> South/North	76	5
South -> North / East	69	1	North -> South/East, East -> South/North	72	2
South -> North / East	66	2	North -> South/East, East -> South/North	66	4
South -> North / East	74	3	North -> South/East, East -> South/North	83	1
South -> North / East	53	2	North -> South/East, East -> South/North	72	3
South -> North / East	68	2	North -> South/East, East -> South/North	57	5
South -> North / East	55	4	North -> South/East, East -> South/North	79	1
South -> North / East	67	2	North -> South/East, East -> South/North	70	3
South -> North / East	62	1	North -> South/East, East -> South/North	80	4
South -> North / East	59	3	North -> South/East, East -> South/North	66	0
South -> North / East	65	1	North -> South/East, East -> South/North	49	5
South -> North / East	63	3	North -> South/East, East -> South/North	82	1
South -> North / East	77	3	North -> South/East, East -> South/North	66	3
South -> North / East	61	5	North -> South/East, East -> South/North	72	1
South -> North / East	46	4	North -> South/East, East -> South/North	65	4
South -> North / East	59	1	North -> South/East, East -> South/North	84	0
South -> North / East	76	2	North -> South/East, East -> South/North	45	4

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Table 1.(continued)

South -> North / East	62	1	North -> South/East, East -> South/North	85	2
South -> North / East	52	3	North -> South/East, East -> South/North	73	0
South -> North / East	57	2	North -> South/East, East -> South/North	83	3
South -> North / East	62	2	North -> South/East, East -> South/North	67	4
South -> North / East	53	4	North -> South/East, East -> South/North	42	2
South -> North / East	70	3	North -> South/East, East -> South/North	69	3
South -> North / East	64	1	North -> South/East, East -> South/North	64	2
South -> North / East	46	2	North -> South/East, East -> South/North	75	1
South -> North / East	62	3	North -> South/East, East -> South/North	68	2
South -> North / East	55	1	North -> South/East, East -> South/North	69	4
South -> North / East	60	4	North -> South/East, East -> South/North		
South -> North / East	49	2			
South -> North / East	53	3			
South -> North / East	60	2			
South -> North / East	49	1			
South -> North / East	64	3			
South -> North / East	58	2			

Observation data indicate that during this observation period, a total of 5,354 non-bus vehicles passed through this traffic intersection, and a total of 203 buses passed through the intersection via the bus lane.

Meanwhile, to further explore the passenger-carrying efficiency of vehicles, the research team also adopted a random sampling method to record the passenger-carrying numbers of some buses and other vehicles when passing through the intersection (Table 2). Based on the recorded data, after calculation, the average passenger-carrying number of non-bus vehicles was 1.3 people, and the average passenger-carrying number of buses was 36.7 people.

Table 2. Number of passengers carried by vehicles

The number of passengers carried by non-bus vehicles	1	1	2	1	1	3	1	1	1	1
	1	2	1	1	2	1	1	1	2	1
	1	1	1	3	1	1	1	2	1	1
The number of passengers carried by bus vehicles	35	26	40	66	12	30	52	20	48	39
	22	50	33	15	42	45	60	28	19	51

Based on the further analysis and summary of the overall traffic flow data, within the 120-minute period of the morning rush hour, the total number of people passing through the non-bus lanes reached 6,960, while the number of passengers transported by the bus lanes was 7,440, which was 6.9% more than that of the non-bus lanes. This data indicates that in the observation section of Zhongguancun Avenue, the traffic efficiency of the bus lanes in terms of carrying passengers was slightly higher than that of the non-bus lanes. However, the data also exposed problems such as fewer passing vehicles per unit time and a relatively low passenger occupancy rate on the bus lanes. This result not only directly reflects the actual effectiveness of the bus lanes in enhancing the public transportation capacity, but also provides a quantitative basis for subsequent optimization of urban traffic resource allocation and adjustment of the planning strategies for bus lanes. (Table 3)

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Table 3. Lane traffic efficiency

	Number of lanes	Total number of passing vehicles	Average passenger capacity per vehicle	Total number of passengers passing through
Bus Lanes	2	203	36.7	7440
Non-Bus Lanes	8	5354	1.3	6960

2.3. Questionnaire survey

Since its first application in 1997, the bus lanes in Beijing have undergone three systematic optimization reforms, achieving iterative upgrades in aspects such as spatial layout and management policies. Currently, the opening hours of the bus lanes on major sections have been adjusted to weekdays only, while opening to non-bus vehicles throughout the day on public holidays and legal holidays. This dynamic management model aims to balance the priority of public transportation and the demand for non-bus vehicle passage. Against this backdrop, in order to gain a deep understanding of the public's perception of the operational efficiency of the current bus lanes and to explore their demands for improvement and suggestions, this study adopted the questionnaire survey method to conduct an empirical research. A total of 163 valid questionnaires were collected, and the Copilot for Power BI intelligent data analysis tool was used to systematically evaluate the operational efficiency and public satisfaction of the bus lanes in Beijing.

The questionnaire designed in this study contains 15 structured questions, forming a multi-dimensional research framework, and conducting in-depth investigations from four core dimensions. In the basic information dimension, questions about respondents' age, gender, occupation, etc., are set; in the travel behavior characteristics dimension, issues such as main travel modes and frequency of bus usage are focused on; in the bus travel evaluation dimension, in-depth understanding is gained of reasons for not taking buses, suggestions for increasing bus occupancy rates, etc.; in the bus lane evaluation dimension, questions are collected specifically about the convenience and efficiency of the bus lanes, as well as suggestions for efficiency improvement, directly reflecting the public's perception of the operational effect of the bus lanes, providing public opinion basis for policy formulation and facility improvement. (Table 4)

Table 4. Design of the research questionnaire

Dimension	Question Number	Measurement Indicator
Basic Information	1~3	Age, gender, occupation
Travel behavior characteristics	4~6	Main mode of transportation, frequency of using buses
Evaluation of bus travel	7~10	Reasons for discontinuation, passenger density, how to increase occupancy rate
Evaluation of bus lanes	11~15	Perception of convenience, efficiency evaluation, optimization requirements

The research was conducted through online random distribution of questionnaires, relying on multiple channels such as Questionnaire Star and social media platforms to ensure the wide range and randomness of the sample sources. Invalid questionnaires with short filling time or logical contradictions were excluded, and finally 163 valid questionnaires were obtained. The basic characteristics of the samples were analyzed, and the results are as follows: (Table 5)

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Table 5. Sample characteristics

Options	Subtotal	Proportion
Male	80	49.08%
Female	83	50.92%
Options	**Subtotal**	**Proportion**
Under 18 years old	2	1.23%
18 - 30 years old	18	11.04%
31 - 50 years old	105	64.42%
51 - 60 years old	25	15.34%
Over 61 years old	13	7.98%
Options	**Subtotal**	**Proportion**
Student	2	1.23%
Staff	112	68.71%
Working from home / Freelance	28	17.18%
Retirement	21	12.88%

From the perspective of gender distribution, there were 80 male respondents, accounting for 49.08%; and 83 female respondents, accounting for 50.92%. The gender ratio was nearly 1:1, effectively avoiding research bias caused by gender imbalance. In terms of age structure, 1.23% were under 18 years old, 11.04% were between 18 and 30 years old, 64.42% were between 31 and 50 years old, making them the main sample group. This group mostly consists of middle-aged professionals and have high daily commuting demands. 15.34% were aged 51-60 years old, and 7.98% were over 61 years old, covering the travel demands of the middle-aged and elderly groups. In terms of occupation distribution, 68.71% were employees, 1.23% were students, 17.18% were stay-at-home/freelancers, and 12.88% were retirees. The sample covers different occupational types,

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enabling a relatively comprehensive reflection of the public's cognition and demands for bus lanes, laying a data foundation for the subsequent precise analysis of public opinions. (Table 5)

2.4. Copilot for Power BI assisting in questionnaire analysis

In the context of the deep integration of digitalization and intelligence, Copilot, as an AI assistant of Power BI, through natural language interaction and automated analysis, significantly lowers the threshold for complex data analysis, enabling users to create reports and obtain data insights more quickly and easily. Its core functions cover four dimensions:

Natural language interaction: Users can describe the desired results in natural language, and Copilot will automatically generate the best visualizations and summaries. This interaction method greatly reduces the threshold for creating reports, enabling non-technical users to easily get started.

Intelligent report creation: Copilot can automatically generate beautiful and interactive reports based on user input, without the need for users to manually drag and drop or adjust visual elements. In addition, Copilot can also provide relevant summaries and insights for reports, helping readers quickly understand the data.

DAX query assistance: In DAX (Data Analysis Expressions), Copilot can assist users in writing complex formulas without having to remember cumbersome syntax or functions.

Semantic model optimization: Copilot can summarize the basic semantic model and suggest content for reports, as well as create summary visual objects for report pages. These functions help users better understand and utilize data models.

This study fully leveraged the technical advantages of Copilot for Power BI to systematically organize and conduct in-depth analysis on 163 survey questionnaires.

Main modes of transportation: Metro is the most dominant mode, accounting for 28%, reflecting the well-developed urban rail transit network and meeting the demand for long-distance commuting. Private cars account for 23%, indicating a high demand for individual motorized travel and also reflecting the economic level of residents and the number of cars they own. Electric motorcycles and buses both account for 15%. They are suitable for short distances and congested roads. Walking accounts for 9% and bicycles 7%, meeting the demand for short-distance travel. Taxis and ride-hailing services account for 2%. (Figure 3)

Bus usage frequency: Most respondents take the bus occasionally, accounting for 102 people (63%), reflecting that most people do not frequently take the bus. Combined with the analysis of reasons for not choosing the bus, due to the slow speed and longer travel time compared to other modes, the bus lacks competitiveness. Users who take the bus 3-5 times a week and daily account for 10%, 9% each, being the stable core customer group of the bus. Users who take the bus 1-2 times a week account for 9%, with a lower frequency, choosing the bus only under specific needs or scenarios. (Figure 4)

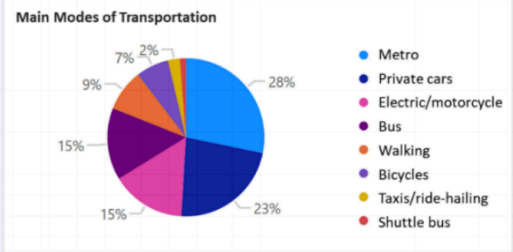

Figure 3. Main modes of transportation

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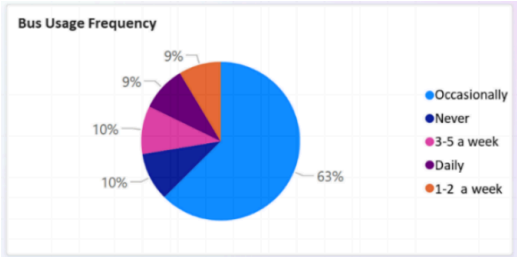

Figure 4. Bus usage frequency

Reasons for not choosing buses: The main reason for passengers not choosing buses is the slow speed and long travel time, accounting for 101 people. This indicates that there is a significant gap between the actual performance of buses and passengers' expectations in terms of running speed and travel time. The second reason is the limited number of bus services with long intervals between them, chosen by 52 people. The number of people choosing inconvenient transfer and crowdedness is both 43. 15 people choose fewer stops, and compared with other factors, the fewer stops have a relatively smaller impact on people's choice of buses. (Figure 5)

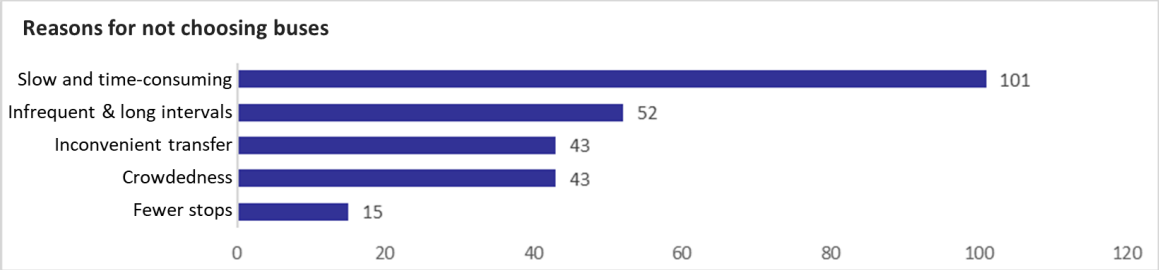

Figure 5. Reasons for not choosing buses

Bus occupancy rate: 37% of the users indicated that most passengers had seats, while 9% said there were many empty seats. This shows that in nearly 50% of the bus travel scenarios, passengers can obtain seats easily and the riding environment is relatively comfortable. However, it also reflects that the occupancy rate and full-load rate of bus passengers are not high, and there is insufficient passenger flow. Those who said the bus was fully occupied by passengers accounted for 28%, indicating that about one quarter of the time, the bus runs at full capacity and resources are fully utilized. Another 26% of the users said that half of the passengers were standing when taking the bus, suggesting that the bus capacity matches the passenger travel demand relatively well. (Figure 6)

The necessary for increasing bus occupancy rate: 42% of the respondents believe it necessary, that means nearly half of the respondents think it is necessary to increase the bus passenger occupancy rate. This reflects their expectations for more efficient utilization of bus resources and further optimization of bus services. 31% of the respondents think it unnecessary, indicating that this group of respondents are basically satisfied with the current bus operation status and bus passenger occupancy rate. Another 26% of the respondents have no opinions on this. (Figure 7)

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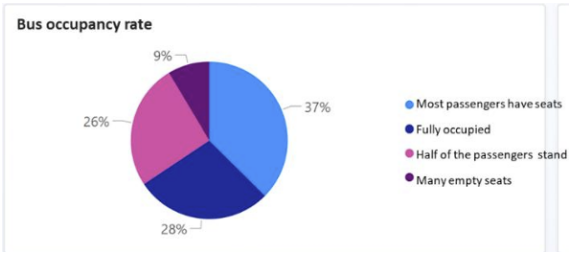

Figure 6. Bus occupancy rate

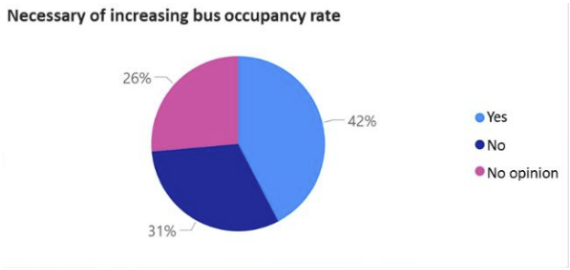

Figure 7. Necessary of increasing bus occupancy

Suggestions for improving the occupancy rate of buses: 101 people supported further optimizing the bus routes, which could support more people and better meet passengers' travel demands. 76 people suggested increasing the bus operation frequency, which could reduce passengers' waiting time and improve travel convenience. 42 people chose to add bus stops, which could facilitate more passengers to take buses nearby and expand the service range of buses. 30 people suggested extending the bus operation time, indicating that a certain number of passengers have travel demands outside the morning and evening rush hours, and extending the operation time could meet the needs of this group of people. 22 people supported lowering the bus fares, indicating that the price factor had an impact on the travel choices of some passengers. 15 people suggested improving services and enhancing the riding experience, and 7 people suggested increasing publicity to encourage green travel on buses. (Figure 8)

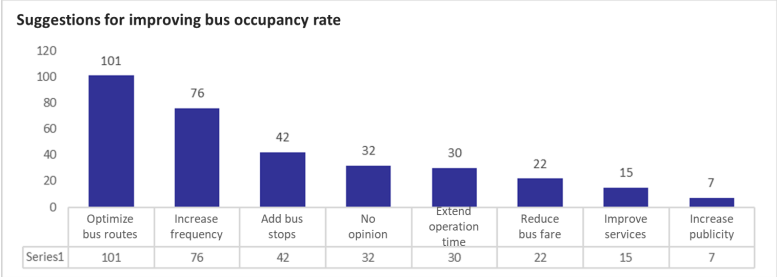

Figure 8. Suggestions for improving bus occupancy rate

Efficiency of bus lane usage: In the evaluation of the usage efficiency of bus lanes, 51% of the respondents (33% + 18%) believe that the current usage efficiency of bus lanes is high or very high. Half of the respondents give a high evaluation and recognition of the usage efficiency of bus lanes, indicating that bus lanes have to some extent guaranteed the travel speed and efficiency of buses. 42% of the respondents consider the usage efficiency of bus lanes to be average, and the combined proportion of those who consider it to be low or very low is 7%. This shows that a portion of the respondents believe that bus lanes have not fully demonstrated their obvious efficiency advantages in actual operation and there is room for improvement. (Figure 9)

Perception of convenience of bus lane: The majority of respondents can feel the convenience brought by bus lanes, accounting for 127 people (78%). This indicates that bus lanes have played a positive role in enhancing the travel experience of buses and protecting the right of buses, allowing passengers to reach their destinations more quickly and punctually. 7% and 15% of the users consider it negative or have no feeling. (Figure 10)

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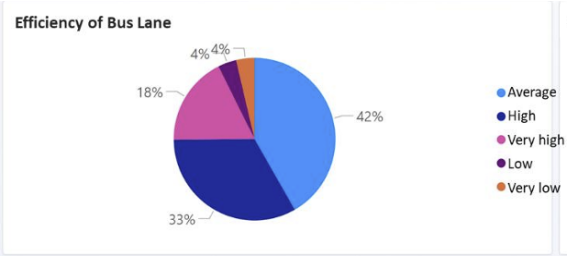

Figure 9. Efficiency of bus lane

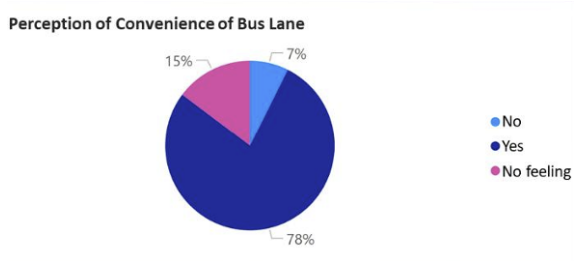

Figure 10. Perception of convenience of bus lane

The necessary for optimization of bus lanes: 57% of the respondents believe it is necessary, that means over half of the respondents think that bus lanes need to be optimized and adjusted. This reflects that there are deficiencies in the setting and management of current bus lanes, which cannot fully meet public needs and has considerable room for improvement. 19% and 24% of the users indicated that they do not need or have no opinions. (Figure 11)

Suggestion of improving the efficiency of bus lanes: 65 people support allowing non-bus vehicles to pass through in snowy and rainy weather, indicating that in special weather conditions, people think the restrictions on the use of bus lanes can be appropriately relaxed to alleviate overall traffic pressure and improve the utilization rate of road resources. 37 people support allowing taxis to pass through, taxis as a supplementary part of public transportation, can be granted the right to pass through the bus lanes. 35 people support allowing vehicles carrying more than 3 people to pass through, reflecting the idea of improving the utilization rate of vehicles through sharing rides, thereby improving the throughput efficiency of bus lanes. 32 people support continuing to add bus lanes. 31 people support allowing non-bus vehicles to pass through bus lanes with ETC payment. Through ETC payment, allowing non-bus vehicles to use the bus lanes under certain conditions can increase the flexibility and resource utilization efficiency of the bus lanes. (Figure 12)

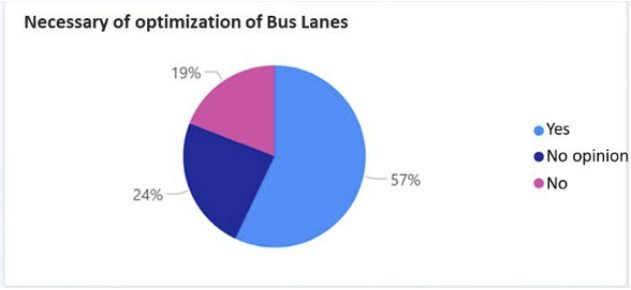

Figure 11. Necessary of optimization

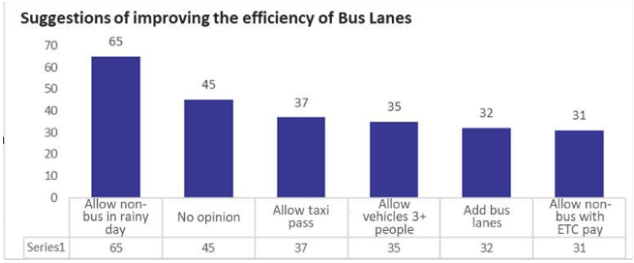

Figure 12. Suggestions of efficiency improving

3. Problems in the bus lane operations and suggestions for improving

3.1. Increasing the occupancy rate of buses

Among the common bus models in Beijing, the occupancy rate of BAIC Foton is approximately 80-90 people, while that of Jinghua Datongdao is around 150-200 people. However, the on-site observation data shows that the average capacity of buses is 37 people, which is less than half of the full-load capacity. Questionnaire surveys also reveal similar issues. Nearly half of the respondents indicated that many seats on the buses they took were empty. The two sets of data fully demonstrate

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that there is idle capacity of bus transportation resources, and has the room for optimization and improvement.

Therefore, it is suggested that firstly, conduct detailed research on residents' travel needs, analyze the characteristics of specific scenarios such as school travel, medical care etc., to optimize the bus route planning. Secondly, scientifically add stops in high-traffic areas to shorten the walking distance; optimize the transfer channels at key nodes to achieve " Seamless Connection ". Finally, promote the environmental and economic advantages of buses, guiding the public to choose buses preferentially.

3.2. Enhancing the comprehensive traffic efficiency of bus lanes

According to the analysis of on-site observations, the non-bus lane can pass through an average of 45 vehicles per minute, while the number of buses passing through the bus lane per minute is less than 2. This is in sharp contrast to the resource allocation of up to 12 bus routes on this section of road. At the same time, the results of the questionnaire survey further confirm this situation - nearly one-third of the respondents pointed out that "fewer trips and longer intervals between buses". The two sets of data fully demonstrate the deficiencies in the frequency of passage and capacity allocation of the bus lane.

It is suggested to enhance the overall efficiency of bus lanes by focusing on two aspects: expanding bus capacity and optimizing access for non-bus vehicles.

Expand bus capacity: By shortening intervals between departures, increasing peak-time services, and extending night operations, establish a high-frequency and wide-spread bus network. Based on passenger flow big data, plan routes and optimize the allocation of bus lanes, activate flexible scheduling such as interval buses and long-stop express buses.

Optimize access for non-bus vehicles: For non-bus vehicles, explore "paid use" and "green incentive" models. Pilot ETC charging, allowing non-bus vehicles to use bus lanes for a fee within a limited time. Implement the "HOV (High Occupancy Vehicle) passage" policy to encourage carpooling, improve road sharing efficiency.

3.3. Strengthen the synergy and coordination between bus lanes and non-bus lanes

Currently, most of the bus lanes in Beijing adopt an operation model based on sections and fixed time periods, lacking comprehensive consideration of dynamic factors such as real-time traffic conditions and weather conditions, resulting in insufficient coordination between the bus lanes and non-bus lanes. During time series analysis, it was found that when severe weather conditions such as heavy rain or snow, the non-bus lanes congestion soared sharply, and the travel time reached more than three times the normal level. Meanwhile, the bus lanes continued to operate according to the established rules, with sparse buses and low efficiency of road resource utilization, creating a stark contrast.

Therefore, it is suggested that in extreme weather conditions, when non-bus lanes are severely congested, vehicles can temporarily use the bus lanes to activate idle resources, alleviate traffic paralysis, and improve road network efficiency. In special sections such as traffic control zones and entrances and exits of expressway main and auxiliary roads, a scientific lane-sharing mechanism should be established, allowing vehicles to share lanes under specific conditions, so as to achieve resource allocation based on demand. At the same time, intelligent monitoring and AI algorithms can be used to monitor traffic flow, dynamically adjust rules, balance the priority of buses and the passage of vehicles, and break through the bottleneck of fixed lanes.

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4. Conclusion

This study comprehensively employs multi-source data and interdisciplinary research methods to conduct a systematic analysis of the operational efficiency of bus lanes. Through long-term dynamic monitoring and time series analysis, it was found that there is a significant correlation between rain and snow weather and traffic congestion, and the commuting time of private cars shows an approximately exponential growth trend with the weather conditions. On-stie observation data confirmed that bus lanes have slightly better passenger carrying capacity than non-bus lanes, but the number of vehicles passing through per unit time on bus lanes is insufficient and the passenger occupancy rate is low. By leveraging the intelligent analysis function of Copilot for Power BI and combining with questionnaire survey data, the research systematized the core problems in the operation of bus lanes and proposed practical improvement plans.

Furthermore, the questionnaire survey results show that citizens have a high recognition and satisfaction with the operational efficiency of Beijing bus lanes, fully confirming the scientificity and necessity of the bus priority policy. This has injected much confidence into the continuous deepening of the bus priority development strategy in Beijing and promoted the optimization and upgrading of transportation resource allocation. It also points out the direction for the dynamic adjustment and precise implementation of subsequent policies.

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