# Quality Analysis and Suggestions for Improvement of Urban Subway Feeder Bus Lines

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**Abstract.** In the urban rail transit system, rail transit as an important hub, can provide people with convenient transfer services, and the bus is an important part of the rail transit system. With the continuous improvement of the material living standards, people's requirements for the quality of public transportation and bus lines are also getting higher and higher. With the continuous expansion of the scale of Fuzhou subway network, the passenger flow is rising rapidly, and the daily passenger flow is more than one million, and the bus operation status connected with it will become an important factor affecting the overall service quality of the city's bus travel chain. This paper selects 8 bus lines passing through the subway station in Fuzhou as the research object, analyzes their quality from two aspects of speediness and reliability, and puts some forward suggestions for improvement.

**Key words:** Urban subway feeder , Bus operation quality , Bus speediness and reliability

## 1. Introduction

Public transportation is an important part of urban infrastructure, while subway and bus, as the main modes of transportation in the city, play an important role in enriching people's travel methods, alleviating urban traffic congestion, improving road resource utilization, improving travel efficiency, and improving travel experience.[1] In recent years, with the continuous construction and development of Fuzhou Metro, four lines of Metro Line 1, 2, 5 and 6 have been built and operated, with an operating mileage of about 111 kilometers. The daily passenger flow of metro has exceeded 1.1 million people, accounting for more than 25% of public transportation trips. During the "14th Five-Year Plan" period.[2] It will also vigorously promote the construction of five new lines with a total length of about 140 kilometers, including metro line 3, Line 8, Line S1, Line 4 phase II and Line 6 west extension.

At the same time, the construction and development of Fuzhou public transport is also constantly advancing, as of the end of 2021, Fuzhou urban area has a total of 6383 buses, 523 bus lines, public transport travel sharing rate of 45.09%. [2] Because the rail transit operating system has the characteristics of fast running speed and high reliability, and the proportion of public transportation trips is increasing year by year, the operating conditions of the buses connected with it will have an important impact on the overall service quality of the bus and subway transportation chain. In order to improve the comprehensive competitiveness of the multi-mode public transport system, it is necessary to optimize and improve the running quality of the subway bus lines.

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This paper first introduces the basic situation of Fuzhou bus lines, and then selects 8 bus lines that pass through subway stations in Fuzhou city, which are No. 39, 43, 330, Metro line No. 3, 95, 41, 150, 48 buses.

The bus arrival time in the evening peak period (5:00PM-7:00PM) on working days and non-working days is counted. The quality analysis is carried out from two aspects of speediness and reliability, and the influencing factors are explored. Effective improvement suggestions are put forward to provide reference for further improving the overall operation level and service quality of the urban public transport system.

## 2. The basic situation of Fuzhou bus lines

From the point of view of operation time: Fuzhou bus operation time is concentrated at 6:00 ~ 22:00. (Daytime bus operation time: 6:30-22:00; Evening service hours: 23:00- 6:00 the next day; Most bus lines in Fuzhou start to operate at 6:00, key lines start to operate at 5:00, small and medium-sized bus lines start to operate at 6:30-7:00). From the point of view of ticket price: urban lines implement the annual one yuan one ticket system, some bus lines fare 2 yuan and above, the maximum is not more than 15 yuan. In terms of departure time, the average time interval is 12-18 minutes, and some bus lines (such as No. 33) are only 6-7 minutes apart. From the perspective of the average waiting time of passengers: according to the 2022 annual traffic report: the average waiting time of Fuzhou ground bus is not more than 6 minutes, only 5.38 minutes, ranking sixth in the country.

## 3. Analysis of the operation quality of the bus line connecting with the subway

There are more than 300 conventional bus lines in Fuzhou city, and only 27 subway connection lines. At present, the public bus-subway transfer largely depends on the conventional bus, so this paper selected 7 conventional bus lines (all have bus stations and subway stations), 1 subway bus connection line, the quality analysis, the data period is 2 working days and 1 non-working evening peak in June 2023 (5: 00PM-7:00PM). The basic characteristics of example lines are shown in **Table 1**.(The data statistics in this article are sourced from Gaode Map)

**Table 1** Selects the basic information of eight research lines

| Line name | Length (KM) | Number of bus stops | Average station spacing (m) | Number of stations connecting to the subway | Number of traffic lights that bus routes pass through (number) |
|---|---|---|---|---|---|
| Route 39 | 20.2 | 33 | 631 | 6 stops | 31 |
| Route 43 | 13.1 | 24 | 570 | 5 stops | 23 |
| Route 330 | 16.1 | 27 | 619 | 6 stops | 29 |
| Connect to Line | 6.2 | 14 | 477 | 4 stops | 14 |

| | | | | | |
|---|---|---|---|---|---|
| 3 | | | | | |
| Route 95 | 15.3 | 25 | 638 | 6 stops | 21 |
| Route 41 | 21.3 | 34 | 645 | 8 stops | 27 |
| 150 way | 20.1 | 30 | 693 | 6 stops | 16 |
| Route 48 | 14 | 29 | 500 | 4 stops | 14 |

### 3.1 Operation quality index setting

In this paper, the quality analysis of bus routes is mainly evaluated from two aspects: speediness and reliability. Among them, the average running speed of bus is used as the evaluation index of bus speediness.[1] Because the volatility of travel time reflects the reliability of road network traffic state and has an important impact on travelers' path selection, this paper uses the volatility of travel time as the reliability index.

(1) The average bus speed, This indicator is the ratio of the average travel time and the length from the start to the end of a bus line during a certain operating period.

(2) Considering the different mileage of different bus routes, it is inappropriate to directly use standard deviation to evaluate the volatility of bus travel time. Therefore, Coefficient of Variation is introduced to eliminate the effect of different bus operating miles. Coefficient of variation is the ratio of the standard deviation of the original data to the mean of the original data. According to the normalization of the coefficient of variation, the weight value of each bus line index is given. [3]

### 3.2 Bus route quality analysis results

Based on the 8 bus lines studied in this paper, the average running speed of the 8 lines is 17.9KM/h from the point of view of the speediness index, and the average running speed of different lines is greatly different. In the survey time range, the average running speed of the 48bus line is the fastest, reaching 24KM/h. The slowest average speed was 13.6KM/h for metro Line No. 3. From the reliability index, the overall volatility of the eight lines studied is small, the average travel time volatility is only 4.80%, the maximum value is 9.04% of the metro line 3, and the minimum value is 1.85% of the metro line 41. The calculation results of the above indexes are shown in Table 2.

**Table 2** Quality analysis of bus routes

| Serial Number | Line name | Speediness indicator | Reliability indicators |
|---|---|---|---|
| | | Average line operating speed (KM/h) | Travel time volatility |
| 1 | Route 39 | 14.8 | 5.28% |
| 2 | Route 43 | 15.2 | 2.72% |
| 3 | Route 330 | 15.2 | 6.14% |
| 4 | Connect to Line 3 | 13.6 | 9.04% |
| 5 | Route 95 | 19.5 | 2.92% |

| | | | |
|---|---|---|---|
| 6 | Route 41 | 18.5 | 1.85% |
| 7 | 150 way | 22.3 | 7.61% |
| 8 | Route 48 | 24.0 | 2.84% |
| | Mean | 17.9 | 4.80% |

## 4. Analysis of the influence on the running quality of the subway bus line

The speed and reliability of bus operation are affected by many factors. In this paper, the average distance between bus stops, the proportion of subway connecting stations in the total stations and the density of traffic lights through the line are selected to analyze three factors.

(1)The influence of average bus stop spacing on running quality

Considering that the average stop spacing of different bus routes is different, this paper divides 8 bus routes into three categories for discussion. According to the statistical data, the average speed of the bus line will continue to increase when the spacing of the bus line is expanded, and the trend is positive. [5]However, the travel time volatility decreases, which improves the stability of the trip. Through the analysis, it is found that the smaller station spacing will cause the bus to stop more frequently, and the detention time spent by the bus will also increase correspondingly. Frequent stops will also increase the instability of the bus journey, thus affecting the volatility of the journey time. See **Table 3**.

**Table3** Effect of average bus stop spacing on running quality

| Average station spacing range (m) | Number of lines | Speediness indicator | Reliability index |
|---|---|---|---|
| | | Average line operating speed (KM/H) | Travel time volatility |
| **<500m** | 1 | 13.6 | 9.04% |
| **500m-635m** | 4 | 17.3 | 4.25% |
| **>635m** | 3 | 20.1 | 4.12% |

(2)The effect of the proportion of subway connecting stations to the total stations on the running quality

In this paper, the proportion of subway connecting stations in the total stations is divided into three sections from low to high. The relevant data of the survey lines are analyzed. The data show that with the increase of the proportion of subway connecting stations in the total stations, the average running speed of bus lines has increased, but the trend has gradually slowed down. The reason may be that when the proportion of subway docking stations in the total stations is small, the number of passengers eager to take the subway for transfer is small, and the impact on the stopping time of vehicles in the whole line is less. When the proportion

of connecting stations increases, the number of passengers with subway transfer needs increases, and the increase of transfer time affects the traffic speed. When the number of passengers in the bus tends to the saturation value, the number of passengers does not affect the stopping time of the vehicle, and the average running speed of the line has no significant effect. The proportion of subway connecting stations in total stations has no significant effect on travel time volatility. See **Table 4**.

**Table 4** The effect of the proportion of subway connecting stations to the total stations on the quality of operation

| Proportion of Metro connection stations to total stations | Number of lines | Rapidity indicators | Reliability Index |
|---|---|---|---|
| | | Average running speed of line(KM/H) | Travel time volatility |
| <0.2 | 2 | 19.4 | 4.06% |
| 0.2-0.235 | 3 | 17.6 | 5.49% |
| >0.235 | 3 | 17.2 | 4.60% |

(3)Effect of traffic signal density on operation quality

In real life, traffic **lights are an important factor affecting the quality of traffic travel. This paper collected the numb**er of traffic lights passed by the relevant bus routes, and calculated the density of traffic lights per kilometer of the trip, and carried out the correlation analysis. The analysis shows that when the traffic light density of the bus route increases, the average running speed of the line decreases significantly. The higher the traffic light density, the more likely to cause congestion; The fluctuation of travel time is also affected by the density of traffic lights, and the randomness of traffic lights affects the stability of travel. See **Table 5**.

**Table 5** Effect of traffic light density on running quality

| The traffic lights that bus routes pass through Density (PCS /KM) | Number of lines | Speediness indicator | Reliability indicators |
|---|---|---|---|
| | | Average line operating speed (KM/H) | Travel time volatility |
| **< 1.3** | 3 | 21.6 | 4.10% |
| **1.3-1.8** | 3 | 16.5 | 3.64% |
| **> 1.8** | 2 | 14.4 | 7.59% |

## 5. Suggestions for improvement

(1) Strengthen technical training for drivers. In the process of bus travel, sometimes there will be problems such as not stopping at the stop, causing passengers to pass the station, road turbulence, causing passengers to travel too fast, and pedestrians to pass the road without slowing down and giving way. Bus Rapid Transit Division of bus group should insist on improving the quality of bus service as the starting point and landing point. Urge the driver to drive safely and provide civilized service. Because the vehicle start, turn, stop and other driving behavior will cause the vehicle running speed changes, resulting in unstable vehicle running, should improve the driver's driving technology, in and out of the bus station, in and out of the intersection, etc., can flexibly drive the bus, make the speed change more stable, reduce the occurrence of rapid acceleration, rapid deceleration. At the same time should be seriously investigated and punished zebra crossing, intersection did not slow down to stop, running red lights, speeding, driving using mobile phones, stop to stop and other violations of discipline, so that the public to enjoy a safe and efficient travel experience.

(2) The priority control strategy of traffic control signals at urban intersections still needs to be improved. Intersection red light will increase the number of bus starts and stops, if can optimize the urban intersection traffic control signal, appropriate optimization of road operation, reduce the number of bus stops, can reduce the impact of intersection signal light on bus operation smoothness, to ensure the priority of public transport while improving the intersection between the trunk line vehicle queuing situation, improve the effective utilization rate of green time, alleviate traffic congestion.[4]In the bus priority technology, the bus or rail transit is given priority at the signalized intersection, which can ensure the punctuality of dispatching operation. In order to ensure the overall smooth flow of traffic, bus priority can be implemented selectively, such as only for buses that deviate from the schedule time or for special lines (such as express lines).[3]

(3) During the holidays, now during the May Day period, Fuzhou City launched free subway and urban bus activities, the public choose to take public transport, on the basis of doing a good job of public transport security, in order to avoid personnel retention, stampede and other events, can be added to open a regular bus, encrypted running trips, extend the operation time, improve the level of dispatching personnel business operations.[6]

(4) In recent years, the public transport enterprises generally have the problem that drivers are in short supply and difficult to recruit. The average salary of bus drivers in Fuzhou Bus Group is 4000-5000 yuan per month, and the salary does not match the work intensity, so it is unable to attract more drivers, resulting in the lack of power of the group in the development of new routes and optimization, which affects the long-term development of the enterprise. To this end, the compensation structure strategy can be adjusted, the hybrid compensation strategy can be adopted, and different compensation strategies can be adopted for different positions. The differences can be reasonably drawn according to the performance of drivers and their contribution degree, so that Fuzhou Bus Group can be more proactive, fair and targeted when making compensation decisions.

## 6. Conclusions

This paper first introduced the analysis of the public transportation system in Fuzhou City, and then selected 8 bus lines for the analysis of line and station on-time rate, respectively, 39, 43,

330, subway connection line 3, 95, 41, 150 and 38 buses, and obtained the line on-time rate of weekdays and weekends, the relative on-time rate of stations and the corresponding on-time rate of stations Absolute punctuality rate, which is analyzed:

(1) As the road length increases, the change in travel time decreases, which means that the change in travel time tends to stabilize as the road length increases.

(2) For the determined coefficient, the fluctuation amplitude of travel time in the case of large traffic demand is stronger than that in the case of low potential demand, which is consistent with the actual situation of traffic flow.

(3) For the determined traffic demand, the greater the coefficient, the smaller the amplitude of travel time fluctuation. This is because the larger the coefficient, the more stable the traffic flow is in a traffic state with lower density. When the coefficient reaches a certain degree, the volatility of travel time must be lower than that of travel time under saturation state.

Then, according to the volatility of bus running time, a method of dividing bus operating environment based on volatility is established, and some strategies and ways to improve punctuality rate are proposed, which can not only improve the operation of bus service, further improve the quality of passengers' travel service, but also provide decision aid for the dynamic scheduling process of buses.[5]

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## 7.Appendix Formula

$$\mathrm{V} = \frac{S}{M}$$

$$M = \frac{\sum_{i=1}^{N} TT_i}{N}$$

$$\mathrm{q_i} = \sqrt{\frac{1}{\mathrm{N}-1}\sum_{\mathrm{i}=1}^{\mathrm{N}} (\mathrm{TT_i} - \mathrm{M})^2}$$

$$\mathrm{v_i} = \frac{\mathrm{q_i}}{\mathrm{M}}$$

$$\mathrm{COV} = 100\% * \mathrm{v_i} = 100\% * \frac{\mathrm{q_i}}{\mathrm{M}} = 100\% * \frac{\sqrt{\frac{\sum_{\mathrm{i}=1}^{\mathrm{N}} (\mathrm{TT_i}-\mathrm{M})^2}{\mathrm{N}-1}}}{\mathrm{M}}$$

V -- The average transit speed, km/h

S -- the length from the start to the end of a bus route; km

M -- the average travel time; h

TT-- one-way travel time of the first shift; h

N -- the total number of bus trips in a given period.

qi-- Mean square error of bus sample time

vi-- Coefficient of variation

COV -- Line travel time fluctuation.

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