

Study on Sustainable Development Strategy of Subway in Medium-sized Cities in China: Case Study of Fujian Cities

Jun-Xiong You

Xiamen University Tah Kah Kee College, China; jsyou774@163.com; Tel.: (+86-0956-628-8390)

Received: Oct 4, 2021; **Accepted:** Nov 4, 2021; **Published:** Mar 30, 2022

Abstract: The development of the subway is closely related to the urban economy in China, and it is also a sign of the development of urban modernization. With sustainable transportation development becoming a global issue, the construction of medium-sized urban subways is limited by the economic volume and is often in the trade-off between construction speed and financial burden. This paper takes the subway cities of Fujian Province -Fuzhou and Xiamen as the research object and analyzes the relative positions of the metros of the two metropolitan areas in 38 metro cities in China. The result of linear regression analysis shows that Fuzhou's progress is slightly conservative, while Xiamen is slightly ahead. There is still space for improvement in the carrying intensity of the subways in the two cities. Comparing the relationship between subway construction and economic growth in medium-sized cities, there is still obvious room for development in subway construction in the two cities. During the research process, actual investigations were conducted to formulate corresponding improvement strategies and suggestions for the operation problems of the two cities for reference by the urban management departments.

Keywords: Subway, Medium-sized cities, Sustainable development, Fujian, Fuzhou, Xiamen

1. Introduction

Sustainable transportation development has long been a global topic. The strategies to address transport sustainability are multifaceted, including demand management, operation management, pricing policy, vehicle technology improvement, clean fuel, and comprehensive land use and transport planning (Deakin, 2001). In China, subway construction is not only a means to solve the sustainable development of urban transportation, but also a symbol of urban transportation modernization. The maximum passenger volume of the subway can reach 45000 people per hour in one direction¹. Although many medium-sized cities meet the requirements of subway construction, it is often difficult to balance the construction progress and financial burden in subway construction because of the high construction funds and follow-up operation costs of the subway. In 2018, the General Office of the State Council issued the "Opinions on Further Strengthening the planning and construction management of urban rail transit", which raised the GDP index of the threshold of urban rail transit construction from 100 billion to 300 billion RMB. The prudent attitude of China's Development and Reform Commission is mainly to avoid excessive investment in the subway, which hinders urban economic development². For this reason, subway construction in medium-sized cities needs to balance between progress and financial burden. According to the incomplete statistics of the China Urban Rail Transit Association, in 2020, the average operating cost per unit vehicle per kilometer of urban rail transit in China was about 24.6 yuan, while the average revenue per unit vehicle kilometer was 15.9 yuan. In 2018, the operating revenue expenditure ratio was 78%, and in 2020, the operating revenue expenditure ratio affected by the epidemic was reduced to 65%³. Cities with insufficient subway revenue continue to bear the pressure of financial subsidies. For cities with insufficient GDP, subway construction may lead to waste of investment and difficult operations in the future (Liu, 2020). Those cities that have built the subway face economic problems of construction scale and effective operation. For the sustainable development of the subway, medium-sized cities need to formulate relevant strategies (You, 2020). Taking Fujian metro cities Fuzhou and Xiamen as examples, we explore the problems of urban metro operation and study the corresponding strategies to facilitate the sustainable development of Metro and drive the positive circular development of the urban economy.

¹ Baidu Encyclopedia. Subway (types of urban rail transit). 2021-05-25.

<https://baike.baidu.com/item/%E5%9C%B0%E9%93%81/21266?fr=aladdin>.

² Subway can't be built if you want to. China Economic Weekly, 2018 (30): 10.

³ China Urban Rail Transit Association, industry statistics. 2021-04-10. <https://www.camet.org.cn/tjxx>.

2. Urban Background

Fuzhou city is the capital of Fujian Province and one of the central cities of the Economic Zone on the West Bank of the Strait approved by the State Council, with a total area of 11,968 km². In 2021, the permanent resident population of the city was 8.29 million, and its GDP reached 100.02 billion yuan in 2020, ranking 23 in China. Fuzhou Metro plans to have 7 routes, which have begun their operation in January 2017. At present, there are 2 routes in operation, with a total operation length of 58.5 km and a construction length of 149.9 km⁴.

Xiamen is a vice provincial city of Fujian Province and a special economic zone of China approved by the State Council, with a total area of 1700.61 km². In 2021, the permanent resident population of the city was 5.16 million. In 2020, the regional gross domestic product (GDP) reached 638.402 billion yuan, ranking 34 in China. Xiamen Metro was planned to have five routes, which started operation in December 2017. Phase I of line 3 was in operation in June 2021, with a total operation length of 98.7 km and a length of 83.7 km under construction⁵.

By 2020, 38 cities in China started subway operations, and the scale of the subway operation of each city is related to the size of GDP (You, 2020). A scatter diagram of the subway route length and GDP volume of each city is shown in Fig. 1. Classified by GDP, Fuzhou belongs to the end of class II City, Xiamen belongs to the end of class III City, and both cities belong to medium-sized cities⁶.

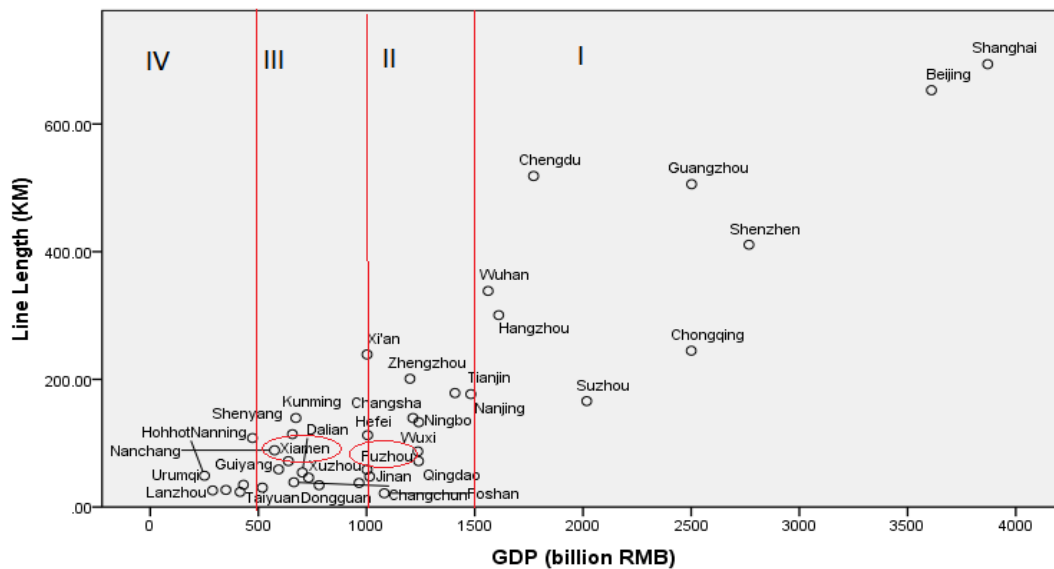


Figure 1. Metro cities classified by GDP.

3. Analysis of Metro Operation Scale

3.1. Analysis of Realized Metro Operation Scale

Based on the data at the end of 2020, the length of subway routes in 38 subway cities is analyzed by linear regression with GDP as the independent variable. The goodness of fit R^2 is 0.798, showing that the overall trend of domestic subway construction increases with the increase in urban GDP. For every 100 billion increase in GDP, the subway operation route increases by 18 km. By examining the standardized scatter diagram of regression residuals (Fig. 2), it is found that by the end of 2020, the length of operation routes of multiple realization cities in class I cities has been significantly higher than the overall trend. The average standard value of residuals in class II cities is -0.46318, indicating that the length of the realized route is significantly lower than the overall trend image. In class III cities, it is -0.06221, and the overall route length is slightly lower than that calculated by GDP volume. The residual analysis results show that class II and III medium-sized cities are relatively conservative, strictly abide by the length of the subway line and the limit of GDP increment, and even do not accelerate the subway construction speed due to GDP

⁴ Baidu Encyclopedia. Fuzhou (prefecture level city and provincial capital of Fujian Province). 2021-05-25. <https://baike.baidu.com/item/%E7%A6%8F%E5%B7%9E/165311?fr=aladdin>.

⁵ Baidu Encyclopedia. Xiamen (prefecture level cities under the jurisdiction of Fujian Province). 2021-05-25. <https://baike.baidu.com/item/%E5%8E%A6%E9%97%A8/212357?fr=aladdin>

⁶ Data source: Urban Rail Transit 2020 statistics of China Urban Rail Transit Association and provincial and municipal statistical bureaus.

increment. Fuzhou belongs to class II cities, and the realized subway construction volume slightly lags behind the overall trend. Xiamen is a class III city, and the realized subway construction volume is slightly higher than the overall trend.

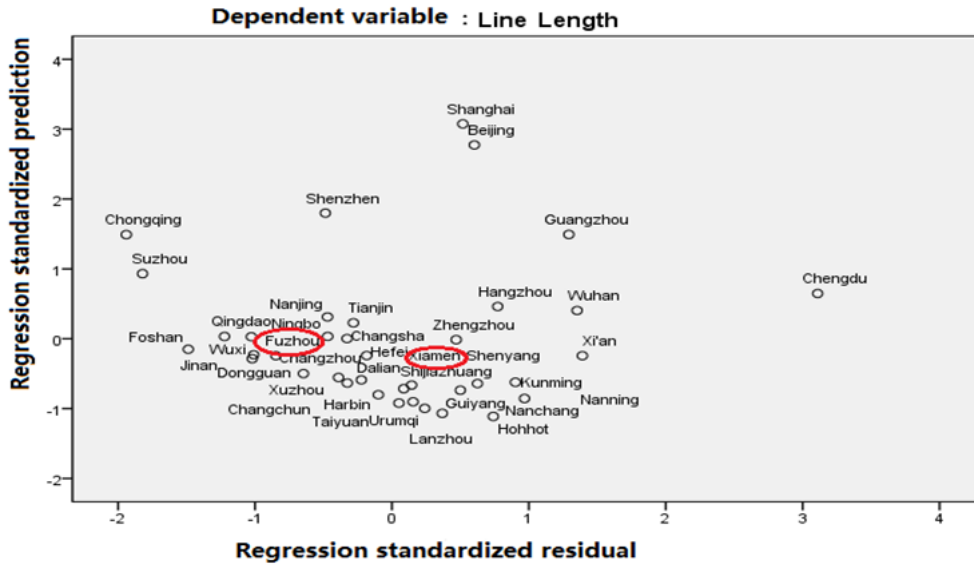


Figure 2. Scatter diagram of regression residuals of metro line length affected by GDP

3.2. Analysis of Passenger Transport Intensity

The route passenger transport intensity of 38 metro cities in China is analyzed, as shown in Fig. 3. It shows that the subway passenger transport intensity in large cities is significantly higher, and the passenger transport intensity of subway lines in Fuzhou and Xiamen is below the average level of medium-sized cities. In 2020, Fuzhou operated 482 trains per day and Xiamen did 687 trains per day, which could be converted into the average number of passengers. They were 534 passengers per train in Fuzhou and 450 passengers per train in Xiamen. If the maximum carrying capacity of each train is 2062, the average carrying rate of Fuzhou is 26% and that of Xiamen is 22%. The data show that the number of subway passengers in the two cities can be greatly expanded.

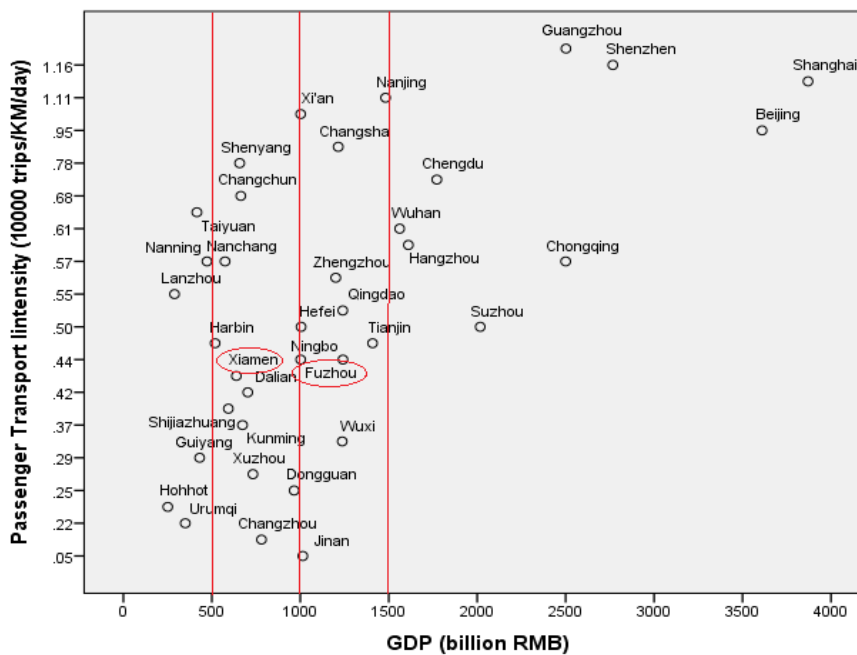


Figure 3. Passenger transport intensity of subway in China’s urban

3.3. *Marginal Incremental Benefits between Subway Construction and GDP from 2016 to 2020*

According to the statistical data of the China Urban Rail Transit Association and the data of various urban statistical bureaus, the GDP of 38 metro cities in 2016–2020 was not increased. The data show that the subway construction could not ensure the growth of the urban economy. During the period, the subway construction in Tianjin, Shenyang, Dalian, Hohhot, and Harbin continued to increase, but the GDP of these cities decreased. However, the increment of subway per kilometer in Shanghai, Beijing, Nanjing, and Wuxi is matched with the GDP increment of more than 10 billion. This figure is 4.094 billion in class I cities, 4.093 billion in class II cities, 3.104 billion in class III cities, and 2.122 billion in class IV cities. Fuzhou and Xiamen have 7.436 and 3.921 billion, respectively. It shows that the subway construction in Fuzhou and Xiamen still has marginal benefits to drive the increase in GDP.

4. **Operation Problem Analysis**

The subway operation in 2020 was investigated in Fuzhou and Xiamen based on a questionnaire survey on passengers' satisfaction. 1050 questionnaires were collected. The questionnaire was based on customer satisfaction theory, expert interview method, analytic hierarchy process, and fuzzy comprehensive evaluation method to investigate subway passenger satisfaction. The results of the field survey and questionnaire interview showed the following problems in operation.

4.1. *Lack of Clear operation indicators and passenger service evaluation system*

According to the rail transit regulations of the two cities, the rail transit operation management organization performs an annual evaluation on the implementation of the annual operation service objectives and implementation plan and reports the evaluation results to the municipal competent department of transportation. This provision is only for the evaluation of the implementation scheme of the operation service provider, and the evaluation indicators are not clearly stated, let alone the requirements of evaluation methods. On the demand side, there are no regulations on passenger service satisfaction evaluation to feedback on consumer opinions, and the system service quality is difficult to manage scientifically.

4.2. *Unclear service evaluation mechanism*

According to the assumption of the rail transit regulations, the rail transit operation management organization shall evaluate the operation service objectives. The self-operation service evaluation results are difficult to truly present the system service level and feedback on consumer satisfaction, which is contrary to the modern management audit mechanism.

4.3. *Unclear external economic feedback*

Subway construction costs are high, construction funds are mostly invested by the government with construction funds, and operation is also mostly subsidized by the government budget. At the end of 2020, only four cities opened for operation in China have made profits in subway revenue, and the fare revenue of many cities was only about 40% of the operating cost. In 2020, the resource revenue of six metro cities accounted for more than 50% of the total revenue, and Xiamen was one of them. The main reason for the government's continuous support is that the external economy of the subway is expected, but if these external economies cannot be fed back, it affects the rational allocation of long-term operating funds and urban development planning of the subway.

4.4. *Unclear revenue strategy*

The construction and operation of the subway are continuous, and there should be a clear revenue plan. Although the subway service does not aim at a profit, it should aim at being responsible for its profits and losses in the long run, and form an operation strategy according to the objectives of different stages. When the initial road network is not complete, the government subsidy is to increase the passenger-carrying rate. However, with the expansion of the system, the proportion of revenue needs to be increased so that the system can develop sustainably. Marketing strategies at all stages should be clear to reduce resource waste and create an external economy. Xiamen has been active in the initial stage of subway operation and launched a free ride service on specific holidays to cultivate a subway passenger source. In addition, compared with the convenience of ticket purchases in Xiamen, Fuzhou Metro does not fully support electronic payment. There are inconvenient situations, which hinders passengers' willingness to take.

4.5. *Traffic integration needs to be improved*

With the gradual improvement of the local railway network, the role of urban public transport transforms into a feeder service. At present, the bus connection service is just in its infancy and needs to be continuously improved. Subway is the backbone service of urban transportation. It must also connect with the long-distance transportation system. The integration problem is bound to occur, and the difficulty is that the system belongs to different operation units and depends on the coordination of the competent department.

5. Improvement Strategies and Suggestions

Based on the analysis of economic and operation data and the analysis of practical research problems, we propose the following improvement strategies and suggestions for reference.

5.1. *Subway construction should be carried out stably with the speed of economic development*

According to the data from 2016 to 2020, the construction of the Fuzhou Metro was slightly conservative, while Xiamen Metro was slightly optimistic. This is slightly different from the economic and Metro-related development of other domestic cities. During 2021–2025, the construction speed is adjusted with attention to the economic development to avoid slowing down the economic development and causing an excessive financial burden.

5.2. *Clarify revenue plan and strategy of each stage*

Subway fares in Chinese cities are limited by the comparative effect between cities. There is little difference in subway fares. It is not easy to balance revenue and expenditure by relying on fares alone. The complete Metro revenue must take into account other revenue to achieve the profit and loss balance. With the increase of the scale of the route network, the route carrying intensity should be effectively increased. The data show that there is room for a significant increase in the average carrying capacity of the Fuzhou and Xiamen subways. When the road network is denser, the more elaborate service plan probably makes the system more cost-effective and creates better revenue results. The practice of Beijing Hong Kong Metro Company in Beijing can be a reference. Because the company has the participation of social capital, the government has stricter subsidy conditions, but the operation efficiency is good. Because the company has the participation of social capital, the government has stricter subsidy conditions, but the operation efficiency is good. The company's profits mainly come from two aspects: (1) the efficient management and cost control within the company and (2) the substantial growth of passenger flow has brought more than expected benefits to the company. In the operation agreement, the government has detailed and clear requirements for the service level, quality, and safety guarantee provided by the company.

5.3. *Clarify and standardize operation indicators and establish passenger service evaluation system*

Since the urban rail transit regulations have regulated that the operation management organization should implement and evaluate the implementation scheme of service objectives, the evaluation contents and indicators should be clear to facilitate system inspection. The practice of the Taipei MRT company can be a reference. The company has four indicators: safety, speed, comfort, and service. There are sub-indicators under four indicators. The sub-indicators are set with target figures to be achieved. The operating company shall publish these service indicators regularly according to law and implement the evaluation work. The passenger service evaluation system is established on this basis, the evaluation indicators and weights are set, and the sampling evaluation is carried out on passengers regularly as the correction of the system service process to maintain high-quality subway service. According to the survey results of Fuzhou Metro passengers, passengers are satisfied on the whole. They are not satisfied with the noise, station and surrounding indication maps, ticket purchase methods, and network signals, which need to be further improved.

5.4. *Quote the third-party service evaluation system*

The results of service evaluation may affect the performance evaluation of the corresponding departments of the operating unit. Therefore, modern management methods mostly adopt the third-party service evaluation system to achieve fairness.

5.5. *Clarify external economic contents of subway service*

Government departments need a clear understanding of the external economy generated by subway services. In this way, the tax collection of external economies benefiting from the subway system service is reasonable, and the government's operation

subsidy for the subway becomes reasonable. The practice of Shenzhen Metro can be a reference. Shenzhen Metro clearly understands the external economy of Metro services. In terms of revenue projects, the more direct external economy is directly included in Metro revenue. Through the joint development of metro stations and real estate, Shenzhen Metro has been profitable since 2016. The revenue of Shenzhen Metro not only comes from the real estate revenue but also from the long-term revenue of the integration of commercial operation, advertising media, communication information, cultural development, property revenue, and subway services.

5.6. Establish an urban transportation integration system with subway as backbone

With the gradual operation of the local railway network, the backbone position of the subway in urban transportation services becomes more obvious. The role of the original public transport system must be transformed into a connecting function to avoid the waste of traffic resources. The integration of the urban transportation network inevitably leads to the conflict of operation interests, so the transportation administrative department should be given complete power to effectively achieve the integration of various public vehicles in the network, schedule, and transfer concessions.

6. Conclusions

Subway is a high-value transportation mode with obvious characteristics of economies of scale, and the positive development relationship between subway construction and the urban economy is also clear. The subway in medium-sized cities must be more cautious in the process of pursuing sustainable development. More than half of China's existing subway cities still belong to medium-sized cities, which is more noteworthy. The data analysis result of 38 subway cities in China shows the direction for the sustainable development of the subway in medium-sized cities to adjust the suitability of construction speed and financial burden. Through the case study of the Fuzhou and Xiamen metro, the problems in the operation and management of medium-sized cities and the solutions are found. Only by maintaining high-quality operation services, can subway construction develop continuously and provide stronger development for the urban economy. More convenient route networks and effective operations are the basis to ensure high-quality services. The problem of subway operation cost burden must be faced by the government, passengers, and enterprises by the urban government department. For the sustainable development of urban subway, government departments have the responsibility to clarify the economic benefits of subway construction, distribute the burden proportion of all parties under the most favorable thinking of urban development, and create a win-win environment for subway operation and urban economic development.

Funding: This research was funded by Fujian Philosophy and Social Sciences Planning Project, Grant No. FJ2019B110.

Acknowledgments: Thank the anonymous reviewers for their valuable comments.

Conflicts of Interest: "The authors declare no conflict of interest."

References

1. Deakin, E. (2001). Sustainable Development & Sustainable Transportation: Strategies for Economic Prosperity, Environmental Quality, and Equity (Unpublished Master's Thesis) . University of California Transportation Center.
2. Liu, T. (2020). Research on index analysis and control of subway operation cost (Unpublished Master's Thesis) . *Finance and accounting study*, 03:137+139.
3. You, L. F. (2020). Research on the development mode of "Subway + property" of Xiamen rail group (Unpublished Master's Thesis) . Gansu Province: Lanzhou University of Technology.
4. Sun. Y. (2018). Research on the relationship between subway mileage and urban economic development level (Unpublished Master's Thesis) . *Taxation*, 12 (22): 210.
5. Zhang, Y. & Xu, H. Z. (2011). Exploration on the construction conditions and scale of rail transit in Harbin in the near future (Unpublished Master's Thesis) . *Urban rapid rail transit*, 24 (04): 65-68 + 73.
6. Chen, Y. (2020). Research on PPP financing mode of urban rail transit (Unpublished Master's Thesis) . Fujian Province: Fujian agriculture and Forestry University.
7. Zhang, L. D. (2017). Study on the development model of "Metro ecosystem" in Fuzhou (Unpublished Master's Thesis) . Fujian Province: Fujian agriculture and Forestry University.
8. Li, J. G. (2015). Research on the development strategy of Xiamen urban rail transit (Unpublished Master's Thesis) . Fujian Province: Overseas Chinese University.
9. Liu, Y. X. (2016). Study on PPP model of transportation infrastructure construction in Xiamen (Unpublished Master's Thesis. Fujian Province: Fujian Normal University.

10. Liu, Y. (2019). Research on subway and urban economic development (Unpublished Master's Thesis. *National circulation economy*, 6: 84–85.

Publisher's Note: IJKII stays neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Copyright: © 2021 The Author(s). Published with license by IJKII, Singapore. This is an Open Access article distributed under the terms of the [Creative Commons Attribution License](https://creativecommons.org/licenses/by/4.0/) (CC BY), which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited.