Analysis of the Causes and Countermeasures of Low Passenger Flow Effect of Tram Lines in China

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Abstract—The development of modern tram in China is very rapid while the passenger flow effects of many existing tram lines are not as good as expected. In order to find out the main causes and countermeasures, this paper compares the passenger flow effects of 49 tram lines at home and abroad by indicator named passenger flow intensity. Then the impacts of land exploitative intensity of nearby regions, average distance between stations and traffic conditions of the same corridor on passenger flow effect are analyzed based on specific cases. Suggestions of strengthening land exploitative intensity of regions along the tram line, shortening the average distance between stations, avoiding setting tram line on the corridor where road traffic is not heavy or there are multiple parallel rail transit lines are finally made to improve passenger flow effect of tram line.

1. Introduction
Modern tram has the advantages of reliable operation, comfort, energy saving, environmental protection and so on. Although modern tram’s passenger capacity is less than that of metro or light rail, its engineering cost is relatively low and its track can be laid on reconstructed road directly. Therefore, many cities around the world have built several tram lines for purposes like meeting the small or medium scale of daily travel demands of residents, enhancing the convenience of travelling within the city and connecting some famous scenic spots for sightseeing.

The development history of modern tram in China is later than abroad, but its development speed is quite fast. Since the opening of TEDA Modern Guided Rail Tram Line in 2007, there are 24 tram lines in China (excluding 5 traditional tram lines) by the end of March 2019, and the total line length is about 294.6km[1]. However, there is a common problem in the operation of tram lines, that is, the actual daily passenger flow is far lower than expected[2]. Most of these tram lines have become the economic burden of city because of low passenger flow effect[3].

Thus, in order to find effective measures to improve the passenger flow effect of the operated lines, as well as providing some design experience for the tram lines to be built, it’s necessary to find out the main causes of low passenger flow effect by analyzing the cases of operated lines at home and abroad. The next section compares the actual passenger flow effect of tram lines at home and abroad to find the differences. Then, the main causes of low passenger flow effect are discussed based on specific cases. The suggestions for improving passenger flow effect are made subsequently. The paper concludes with a summary section.
2. Comparative Analysis of Passenger Flow Effect of Tram Lines at Home and Abroad

Passenger flow intensity refers to the daily passenger quantity per kilometer of line (passenger/day/km), which is an important indicator in many passenger flow analyses and can eliminate the influence of line length[4]. Since the length of each tram line is different, we choose passenger flow intensity to evaluate the passenger flow effect. The equation to calculate passenger flow intensity is as follow:

\[ I = \frac{Q_d}{L} \quad (1) \]

Where \( I \) is the passenger flow intensity, \( Q_d \) is the average daily passenger quantity, \( L \) is the line length.

Through data collection, we have obtained the open operation information of 49 tram lines at home and abroad. 15 of them are in China and the statistical year of their data is 2018[1]. The rest of them are composed of 5 tram lines in Lyon with data in 2016[5], 10 tram lines in Paris with data in 2016[6] and 19 tram lines in Melbourne with data in 2013[7]. The distribution of passenger flow intensity of tram lines in China is shown as Fig. 1 and that of tram lines in foreign countries is shown as Fig. 2, respectively.

By comparing the results in Fig. 1 and Fig. 2, we can find that:

(1) In China, Shenzhen Tram Line 1 has the highest passenger flow intensity, which is 2200 passenger/day/km. Suzhou SND Tram Line 2 and Chengdu Modern Tram Line 2 have the lowest passenger flow intensity, which is 200 passenger/day/km. The proportion of tram lines with passenger flow intensity less than 1000 passenger/day/km is 73.3%.

(2) In foreign countries, Île-de-France Tramway Line T3a has the highest passenger flow intensity, which is 16700 passenger/day/km. Melbourne Tram Route 82 has the lowest passenger flow intensity, which is 400 passenger/day/km. The proportion of tram lines with passenger flow intensity less than 1000 passenger/day/km is 20.6% while the proportion of tram lines with passenger flow intensity more than 2200 passenger/day/km is 47.1%.

Judging from the proportion of tram lines with passenger flow intensity less than 1000 passenger/day/km and the highest passenger flow intensity, the overall condition of passenger flow effect of tram lines in foreign countries is much better than that in China. In order to find out the main causes of this result, several specific lines are studied in the next section.

![Figure 1. Distribution of passenger flow intensity of tram lines in China](image-url)
3. Main Causes of Low Passenger Flow Effect

The main function of tram is to bring passengers to their destinations in time. These passengers can be divided into two types: passengers living in regions along the tram line, passengers attracted by the area along the tram line but live in regions far away from the tram line. Therefore, the land exploitative intensity of regions along the tram line should have influences on the passenger flow effect. However, for the lines with similar land exploitative intensity, the accessibility of arriving at station and leaving from station to the destination will be a crucial factor for passengers’ willingness to take the tram[8], which is measured in a macroscopic view by the average distance between stations in this paper. Besides, the influences of competition for passengers between the tram and other traffic systems should be taken into account.

Hence, the impacts of land exploitative intensity of nearby regions, average distance between stations and traffic conditions of the same corridor on passenger flow effect of tram line are analyzed based on specific cases in this paper.

3.1. Impact of Land Exploitative Intensity of Nearby Regions

According to the land use and numbers of different types of buildings in the region, four levels of land exploitative intensity are defined in this paper:

1) Very High Level: Regions with large shopping mall or trading areas, office building and large public facilities (such as hospital, comprehensive transportation hub).

2) High Level: Regions with large residential areas, small or medium scale of trading areas and public facilities.

3) Medium Level: Regions with industrial park, university, parking lot, small or medium scale of residential areas and public facilities.

4) Low Level: Regions with greenbelt, factory and warehouse.

The examples of each level are shown as Fig. 3.

Three tram lines in China and three tram lines in Lyon with obvious difference in passenger flow intensity but similar function orientation are selected to make up two groups for comparative analysis. The land exploitative intensity of regions along these tram lines are investigated through the street view information provided by online satellite mosaic image mapping. The field of investigation is the region within 500m from tram line[9]. The investigation results of two groups are shown as Fig. 4 and Fig. 5, respectively.
Figure 3. Examples of regions with different land exploitative intensity

Figure 4. Land exploitative intensity of regions along some tram lines in China
In Fig. 4, Shenzhen Tran Line 1 has the highest land exploitative intensity as well as the highest passenger flow intensity. Both the land exploitative intensity and passenger flow intensity of Huai’an Modern Tram Line are higher than those of TEDA Modern Guided Rail Tram.

In Fig. 5, Lyon Tramway Line T1 has the highest land exploitative intensity as well as the highest passenger flow intensity. Lyon Tramway Line T2 and Lyon Tram Line T3 have similar land exploitative intensity but big difference in passenger flow intensity. Since the operation history of TEDA Modern Guided Rail Tram is similar to that of Lyon Tramway Line T3, their difference in passenger flow intensity may be mainly caused by the land exploitative intensity of their nearby regions. Although tram lines with similar land exploitative intensity also have difference in passenger flow intensity because of the operation history, person trip characteristics and many other factors[10], from the results in Fig. 4 and Fig. 5, we can find that land exploitative intensity of nearby regions generally has a positive correlation with passenger flow effect of the tram line.

### 3.2. Impact of Average Distance between Stations

From the results of Fig. 5, we can also find that the lengths of Lyon Tramway Line T2 and Lyon Tramway Line T3 are close. Since both of them have an operation history more than 10 years and their land exploitative intensity are similar, the difference in their passenger flow effect may be caused by the accessibility, which is measured in a macroscopic view by the average distance between stations in this paper.

Tram station is the place that receives travelers living and working in surrounding areas and also generates travelers coming from distant areas but planning to go to surrounding areas. Once the number of stations increases, the increased stations will not only turn nearby residents into potential passengers, but also attract travelers who want to go to the nearby area. Thus, the passenger flow effect of Lyon
Tramway Line T2 with 29 stations is better than that of Lyon Tramway Line T3 with 11 stations as expected.

Fig. 6 shows the distributions of average distances between stations of tram lines in China, France and Melbourne. We can find that the values of Melbourne are far smaller than those of China and France clearly. This may be due to that trams in Melbourne run mainly in the urban area and their function orientation is similar to typical public bus. On the whole, the average distances between stations of tram lines in China are longer than that of France. Since the passenger flow effects of tram lines in France are generally better than those of tram lines in China, relatively long average distance between stations may be one of main causes of low passenger flow effect.

Figure 6. Distributions of average distances between stations of tram lines in different countries

3.3. Impact of Traffic Conditions of the Same Corridor

The existence of a tram line provides residents with additional travel tool option. Therefore, the tram has to compete with private car, public bus and other rail transit in order to obtain passengers.

Since private car and public bus usually travel faster than trams when the road is not congested, the tram line serving corridors with heavy traffic may have a strong attraction for nearby residents and workers. The locations of tram lines in Paris and Lyon are mainly concentrated in the urban area or urban core of satellite city whose urban expressways and urban arterial roads are always congested in peak hour. In this case, people may be more inclined to choose trams for its advantages in punctuality.

In contrast, most of tram lines in China are located in suburb or economic development zone where road traffic is not heavy, leading to the disadvantage of tram in the competition with private car or public bus. Fig. 7 shows the geographical locations of Tianjin urban core and TEDA Modern Guided Rail Tram line whose passenger flow intensity is 500 passenger/day/km. Since the land exploitative intensity of place far away from urban core is generally not high while the road traffic condition is quite good for traveling by private car or public bus, it’s not surprising that the tram line has low passenger flow effect.
In addition to competing with road traffic, tram sometimes has to compete with other rail transit if they are serving the same corridor. Fig. 8 shows the line alignments of tram lines which are partly parallel to Melbourne Tram Route 48. Although Melbourne Tram Route connects the eastern suburbs and urban core, having a strong characteristic of commuting, its passenger flow intensity is only 1500 passenger/day/km.

This result may be caused mainly by that Melbourne Tram Route 48 is parallel to other tram lines in many sections. From Fig. 8 we can find that Melbourne Tram Route 48 is parallel to Tram Route 109 in section AB, Tram Route 75 in section CD, Tram Route 11, 12, 75 and 109 in section DE, Tram Route 11 in section EF. The existences of tram lines parallel to Melbourne Tram Route 48 have shared the total passenger flow, which may be the main cause of the low passenger flow effect of Melbourne Tram Route 48. Therefore, the passenger flow competition of several tram lines on the same corridor should be avoided as far as possible.

4. Suggestions for Improving Passenger Flow Effect of Tram Line

According to the analyses of main causes of low passenger flow effect based on specific cases, several suggestions for improving passenger flow effect are made as follows:

(1) For the existing tram lines, it’s necessary to actively strengthen the land exploitative intensity of regions along the tram line based on the overall urban development planning to increase potential travel demands. For the planning tram lines, the current and future land use conditions of nearby regions should be fully considered. When selecting the line alignment and station location, regions with high land exploitative intensity should be given priority in most cases.

(2) For a better accessibility of tram line, average distance between stations should not be too long, especially for tram lines mainly located in urban areas. In this way, more residents and workers may be willing to take the tram. However, for the suburban section of tram line, it would be better to only set up stations near accumulating and dispersing centers of passenger flow, which can shorten the tram’s travel time between urban and suburban areas.
(3) The traffic conditions of corridor served by tram line should be fully considered when planning. On the one hand, the setting of tram line in the area where road traffic is not heavy should be avoided. On the other hand, several rail transit lines should not be set as parallel lines in the same corridor which may cause passenger flow competition of these lines.

5. Summary
This paper compares the passenger flow effects of 49 tram lines at home and abroad by indicator named passenger flow intensity, which shows that the overall condition of passenger flow effect of tram lines in foreign countries is much better than that in China. In order to find out the main causes and countermeasures, the impacts of land exploitative intensity of nearby regions, average distance between stations and traffic conditions of the same corridor on passenger flow effect are analyzed based on specific cases. These analyses show that strengthening the land development intensity along the tram line, shortening the average station spacing, and setting the tram line on the corridor with busy road traffic and no other parallel rail transit lines are effective ways to improve the passenger flow effect of tram lines.

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