Traffic Design Method for the Intersection in the Center District of Quanzhou Tram

Dong-ping Li\textsuperscript{1,*} and Sheng-yi PAN\textsuperscript{2}

\textsuperscript{1}Shanghai Urban Construction Design and Research Institute (Group) CO., LTD. Shanghai, China
\textsuperscript{2}Quanzhou Urban-Rural Planning Bureau, Quanzhou, China
\textsuperscript{*}Corresponding author

Keywords: Tram, Center district, Intersection, Traffic design, Quanzhou.

Abstract. In order to coordinate the setting of tram at the intersection in the center district, taking the typical intersections of Quanzhou streetcar line 1 as an example, based on the traffic impacting analysis and construction conditions, the paper presented the design methods for intersections with ground or underground layout. As well, the key points of the design were explained. The traffic evaluation showed that the traffic service was adapted. The scheme got the balance with the operating efficiency of the tram and the traffic demand, which provides a reference for the construction of the tram in the center district.

Introduction

As of the end of 2017, the operating tram mileage reached 232km, the constructing tram mileage exceeded 585km, and the recently planned constructing tram mileage exceeded 2500km [1] in China Mainland. The tram has started to become one of the important bus modes in the city. There are three application modes of tram in China: as the extension or additional lines of rail transit, as the backbone bus lines in cities, and as the tourism distinctive bus lines [2]. Among them, the tram as the backbone bus lines laid in the city center inevitably, which is the important way to exert the technical characteristics and advantages of the tram to realize sustainable construction and operation.

Traffic organization along the tram [3], especially the intersection design [4], are the design focus of the tram. Because the traffic flow is large in center district and it is difficult to broaden the road, how to coordinate the crossroads of tram and road traffic access right is one of major difficulties during the tram construction process. Quanzhou tram line 1, as the backbone of public transport in Quanzhou recently, lays through the urban center district. This paper mainly studies the traffic design of the intersection of the two main roads in the center district, Wenling Road and Quanxiu Street, which has a reference function to the traffic design of the tram intersection in the center district.

Program of Quanzhou Tram Line 1

Development Background of Quanzhou

Quanzhou is located in the southeastern part of Fujian Province, whose mainly development area including Quanzhou, Jinjiang and Shishi around Quanzhou Bay. The planned resident population is 5.4 million by 2030. The urban space structure forms a “one bay, two wings and three belts”, which shows a significant spatial structure of the combined city features: “multi-group, multi-center, small concentration, large space.”

The transport demand characteristics of Quanzhou were: large total and multi-center concentration, long average travel distance and discrete travel distance distribution, bus target differences and multi-level distribution, and so on. Therefore, on the one hand, the large bus corridor has not yet been formed, so the rail transit will be constructed for a long time. On the other hand, the traffic congestion in the center district has become increasingly serious. It is necessary to build a tram as soon as possible to build a rapid transit system.

672
Tram Line 1

Quanzhou tram line 1 is from the Railway Station to Houzhu Port Station, length 24.84 km, set up 28 stations and the average station spacing 887 m. The line is laid out crossing East-West Avenue, Puxian Road, Quanshan Road, Shaolin Road, Wenling Road, Quanxiu Street, Donghai Street, Fudong Road, Haixing Street, Fenghai Road [5].

![Figure 1. Location map of Quanzhou tram line 1.](image)

The line is functioned as the backbone of public transport of Quanzhou, the livelihood line and the tourist line. A series of major passenger transport hubs such as Quanzhou Railway Station and the Passenger Transportation Center, as well as schools, hospitals and municipal administrative centers are all connected by the line to meet the passenger traffic demand. A series of major tourist attractions such as Qingyuan Mountain, Old Town, Zhenwu Temple and Houzhu Port are connected by the line to promote tourism and leisure development. Therefore, the line adopts the segregated tramway, which is laid mainly on the ground in the road. In the local nodes of the center district, the line is laid underground.

Traffic Design Method of Intersections in Center District

Traffic Design Principles of Intersections

Quanzhou tram line 1 is laid through the center district, including two main roads: Wenling Road and Quanxiu Street. The status quo of the motorway is two-way four lanes, with non-motorized lanes and widening conditions on the road sections. However, the major traffic jams point concentrated at the intersection. The design principles for the intersections are as follows:

(1) Laid mainly on the ground. Tram is the public transport with laid mainly on the ground. The same way, tram should be laid on the ground when crossing the intersections. So, it is bound to make the necessary adjustments to the current traffic organization of the intersections after the tram construction.

(2) Interchange separation of partial intersection. There are two main principles of the separation. First, the current situation of traffic congestion has been saturated. The traffic impact is beyond the acceptable range after the tram construction. Second, the project is limited to broaden the intersection. It is impossible to ease traffic congestion on the ground.

The traffic flow and reconstruction conditions at the intersections of Wenshen Road and QuanXiu Street are analyzed (Table 1), and two design methods of ground layout and underground layout are put forward.
Table 1. Status quo of intersections and comparison of traffic adaptability after tram construction.

<table>
<thead>
<tr>
<th>intersections</th>
<th>average delay (s)</th>
<th>status quo</th>
<th>level of service</th>
<th>average delay (s)</th>
<th>stops number</th>
<th>level of service</th>
<th>broaden conditions</th>
<th>recommend</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wenling Road-Donghu Street</td>
<td>50.1</td>
<td>1.55</td>
<td>D</td>
<td>105.1</td>
<td>2.67</td>
<td>F</td>
<td>N</td>
<td>underground</td>
</tr>
<tr>
<td>Wenling Road-Fengze Street</td>
<td>65.6</td>
<td>2.41</td>
<td>E</td>
<td>58.6</td>
<td>2.17</td>
<td>E</td>
<td>Y</td>
<td>ground</td>
</tr>
<tr>
<td>Wenling Road-Jinhua Street</td>
<td>76.7</td>
<td>1.95</td>
<td>E</td>
<td>99.3</td>
<td>2.02</td>
<td>F</td>
<td>N</td>
<td>underground</td>
</tr>
<tr>
<td>Wenling Road-Quanxiu Street</td>
<td>74.2</td>
<td>3.08</td>
<td>E</td>
<td>66.6</td>
<td>2.83</td>
<td>E</td>
<td>Y</td>
<td>ground</td>
</tr>
<tr>
<td>Quanxiu Street-Tian’an Road</td>
<td>78.4</td>
<td>2.55</td>
<td>E</td>
<td>89.9</td>
<td>3.38</td>
<td>F</td>
<td>N</td>
<td>underground</td>
</tr>
<tr>
<td>Quanxiu Street-Citong Road</td>
<td>72.3</td>
<td>1.85</td>
<td>E</td>
<td>81.5</td>
<td>1.89</td>
<td>E</td>
<td>N</td>
<td>ground</td>
</tr>
<tr>
<td>Quanxiu Street-Pingshan Road</td>
<td>77.8</td>
<td>2.08</td>
<td>E</td>
<td>98.8</td>
<td>3.88</td>
<td>F</td>
<td>N</td>
<td>underground</td>
</tr>
</tbody>
</table>

Through the evaluation of the ground layout at the intersections, the layout of intersections are determined based on the principle of coordinated operation of trams and road traffic. Three intersections are laid on ground: Wenling Road-Fengze Street, Wenling Road-Quanxiu Street, Quanxiu Street-Citong Road. Four intersections are laid underground: Wenling Road-Donghu Street, Wenling Road-Jinhua Street, Quanxiu Street-Tian’an Road, Quanxiu Street-Pingshan Road.

**Traffic Design Methods of Ground Layout**

It takes Wenling Road-Fengze Street intersection as an example to illustrate the design method of tram ground layout. The current situation of Wenling Road-Fengze Street intersection adopted the canalization islands. There are 4 entrance lanes and 3 exit lanes in the direction of Wenling Road, and 4 inlet roads and 3 outlet roads in Fengze Street direction (Figure 2.).

![Figure 2. Status quo of Wenling Road-Fengze Street intersection.](image1)

The tram is laid on ground, and the stations were set up at the intersection. The intersection is transformation designed with the ground canalization (Figure 3.).

![Figure 3. Ground design program of Wenling Road-Fengze Street intersection.](image2)
The key points of the design include:

1. The tram stations should adopt the staggered lateral stations located at the exit lane, which correspond to the left turn lane at the intersection entrance lane. The design method balance the utilization of the space on both sides of the road and the deviation of the driving track of the vehicle. At the same time, pedestrian crossing stop zone could be set with the stations space.

2. The width of the entrance lanes could be moderate compressed, taking 2.8m as the minimum width of the entrance lanes.

3. The original canalization islands are canceled and the right turning radius was reduced, thus increasing the space in the intersection. Although the width of sidewalks of the road sections are properly reduced, the pedestrian space area is not reduced in the intersection.

4. In addition to the transformation of the direction of Wenling Road, where the tram located, the direction of Fengze Street are also transformated at the same time, whose entrance lanes are increased.

Therefore, through the comprehensive design of the intersection, it don’t reduce the number of entrance lanes and ensure the pedestrian walking space. The program evaluation results of the implementation show that both meet the tram and the road traffic requirements.

**Traffic Design Methods of Underground Layout**

It takes Wenling Road-Donghu Street as an example to illustrate the design of tram underground layout. There are 3 entrance lanes and 2 exit lanes in the direction of Wenling Road, and the space of the north by the building constraints on both sides cannot be boarded. There are 3 entrance lanes and 2 exit lanes in the direction of Donghu Street on the old city district without widening conditions on both sides (Figure 4.).

![Figure 4. Status quo of Wenling Road-Donghu Street intersection.](image)

The status quo traffic flow saturation of intersection is D-class, but there is no widening conditions subject to engineering conditions. If the tram is laid on the ground and the stations need to set at the intersection exit lanes, they will occupy directly 3 lanes. This will result in only 2 entrance lanes and 1 exit lane in the direction of Wenling Road, whose traffic impact of this result is unacceptable.

Therefore, the intersection using the underground layout (Figure 5.). That is, tram lines and stations are located below the intersection.

![Figure 5. Underground design program of Wenling Road-Donghu Street intersection.](image)
The key points of the design include:

(1) Tram is laid underground. If the social vehicles lanes laid underground, the road space on ground is still not enough to meet the vehicle steering requirements. The tram underground layout could balance the space better for tram and vehicle, and improve the tram travel speed. Relative to the bridge layout, the underground layout impact less landscape on the center district.

(2) The length of buried section should also consider the requirements of canalization of surface traffic and ventilation of the lower section. The ground should be recovered into vehicle lanes so as not to reduce the number of lanes in the intersection area, which could balance the needs of vehicle traffic. Meanwhile, the length of the buried sections should meet the requirements of fire protection and natural ventilation, which could reduce construction and operating costs.

(3) The original canalization islands are cancelled. On the one hand, the area of intersections is reduced and the length of buried sections is reduced. On the other hand, the usable area of intersections is widened. Pedestrian stops, central dividers and the natural ventilation wells can be provided in the intersection.

(4) The underground tram stations are combined with the buried sections. The stations set at the intersection could provide the best service to passengers in the surrounding area. At the same time, tram stations and sections are set on the same floor, which could allow passengers crossing the track. Thus, the transition length between the underground stations and sections should meet the security sight requirements of tram and passenger.

Therefore, the design method with tram underground layout not only meets the function of tram passing and passenger organization, but also coordinates the requirement of social vehicles passing through the main congestion intersections in the center district.

**Evaluation of Traffic Design Programs**

Based on the analysis of traffic service levels and construction conditions at the intersections, four intersections are adapted tram underground layout in the center district (Figure 6.). The level of service evaluated results show that the designs of the intersections could maximize the operational requirements of trams and road traffic (Table 2.). The vehicle traffic service would improve greatly at the intersections of Wenling Road-Donghu Street, Wenling Road-Jinhui Street, Quanxiu Street-Tian'an Road and Quanxiu Street-Pingshan Road. The vehicle traffic service would increase slightly at the two intersections of Wenling Road-Fengze Street and Wenling Road-Quanxiu Street. The vehicle traffic service would maintain the status quo at Quanxiu Street-Citong Road intersection.

---

**Figure 6.** Sketch map of design program in center district.
Table 2. Comparison of service level before and after the tram construction.

<table>
<thead>
<tr>
<th>intersections</th>
<th>status quo</th>
<th>tram completed</th>
<th>program</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>average delay (s)</td>
<td>stops number</td>
<td>level of service</td>
</tr>
<tr>
<td>Wenling Road-Donghu Street</td>
<td>50.1</td>
<td>1.55</td>
<td>D</td>
</tr>
<tr>
<td>Wenling Road-Fengze Street</td>
<td>65.6</td>
<td>2.41</td>
<td>E</td>
</tr>
<tr>
<td>Wenling Road-Jinhuaui Street</td>
<td>76.7</td>
<td>1.95</td>
<td>E</td>
</tr>
<tr>
<td>Wenling Road-Quanxiu Street</td>
<td>74.2</td>
<td>3.08</td>
<td>E</td>
</tr>
<tr>
<td>Quanxiu Street-Tian’an Road</td>
<td>78.4</td>
<td>2.55</td>
<td>E</td>
</tr>
<tr>
<td>Quanxiu Street-Citong Road</td>
<td>72.3</td>
<td>1.85</td>
<td>E</td>
</tr>
<tr>
<td>Quanxiu Street-Pingshan Road</td>
<td>77.8</td>
<td>2.08</td>
<td>E</td>
</tr>
</tbody>
</table>

Summary

The traffic design of the tram at the intersection is the key factor to realize the layout of the tram in the center district. The layout of tram in center district should take into account the operational efficiency of the tram and the traffic requirements of traffic. Taking full account of the traffic impact and project widening conditions, ground or underground layout should be adapt according to local conditions. Taking the intersections in Wenling Road and Quanxiu Street of Quanzhou tram line 1 as the examples, the paper proposed the design programs of the intersections, which provides a reference for the construction of the tram in the center district.

Acknowledgement

This research was financially supported by Shanghai Rising-Star Program (16QB1403000) and Shanghai Urban-Rural Development Transportation Talents Special Funds.

References

[5] Shanghai Urban Construction Design and Research Institute, Feasibility study report of first phase of the project of Quanzhou modern tram (T1 line), 2016.10.