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Research and Suggestions on the Development of Low-Capacity Urban Rail Transit in China

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Abstract: In recent years, the low-capacity urban rail transit in China has developed rapidly. Firstly, the common system and overall development of low-capacity rail transit in China are summarized, including tram, APM, Yunba, and ART. Secondly, this paper comprehensively reviewed the low-capacity rail transit from the aspect of general development, functional aim, operation environment, operation effect, technical system and financial subsidies. The research results found that the urban rail transit system in low-capacity cities lacks guidance and control in the approval process, resulting in a low benefit ratio from investment. The types of systems chosen by various cities are too diverse, making it difficult to achieve scale benefits and reduce construction costs. Most projects have low passenger flow, so public recognition can not be gained. Finally, some suggestions for the follow-up development of low-capacity rail transit in China are proposed: clarifying the development stage of domestic urban transportation, and objectively demonstrating the functional aim of low-capacity urban rail transit; avoiding blindly pursuing diverse system modes, and focusing on improving the efficiency of public transportation; carefully studying the investment benefits of the system, and strictly approving related construction projects.

Keywords: low-capacity urban rail transit; tram; APM; Yunba; ART; function aim; system mode selection; approval criteria; investment benefits

0 Introduction

As a branch of urban public transport, low-capacity urban rail transit has some positive significance in improving rail-transit network coverage and promoting multi-network integration. In some foreign cities, developing low-capacity urban rail transit plays a role in increasing public transport levels, improving travel quality, and enhancing travel attractiveness. With this as a reference, in recent years, some cities in China have initiated the planning and construction of low-capacity urban rail transit. Specifically, some lines have been completed and put into operation. What are the actual developments of these lines? Does their functional aim adapt to urban transport development and environment? Are operational effects as expected? What should be noticed in subsequent development? These questions deserve in-depth discussion and analysis.

1 Development overview of low-capacity urban rail transit

According to passenger-carrying capacity, urban rail transit is generally divided into three levels: large-, medium-, and low-capacity systems. Specifically, low-capacity systems can transport 10 000 passengers per hour unidirectionally, such as trams, automated people mover (APM) systems, Yunba, and autonomous rail rapid transit (ART) (see Fig. 1). Trams and APMs were developed and applied overseas before being introduced into China, while Yunba and ART were developed by Chinese manufacturers and first applied in China. The main technical features of various systems and their applications in China are briefly reviewed below.

Fig. 1 Common low-capacity urban rail transit systems

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1.1 Tram

According to Beijing's Local Standard—Code for Design of Modern Tram Engineering (DB11/T 1707–2019), trams refer to "medium- and low-capacity rail transit systems adopting low-floor, articulated, steel-wheel–rail based, and electrically driven vehicles, enjoying multiple rights of way and mainly traveling on ground lines". Trams were first developed by German Siemens in 1879. Two years later, the world's first tram was built and put into operation in Lichterfelde near Berlin. Then, trams were introduced into China in the early 20th century. In the first half of the 20th century, trams once became the main public transport system in big cities. However, with the vigorous development of the automobile industry after the Second World War, the number of buses and private cars increased rapidly, and trams were gradually eliminated. As a result, fewer and fewer cities in China and other countries retained trams. At one time, only Dalian and Changchun in the mainland of China retained individual lines for continuous tram operation. In recent years, as more attention is paid to traffic congestion and exhaust emission, trams have revived first in foreign cities. Affected by this, Chinese cities began to build trams on a large scale after 2005 (see Fig. 2). By the end of 2022, tram lines in 24 cities in the mainland of China had been put into operation, with a total operating mileage of 580.72 km.

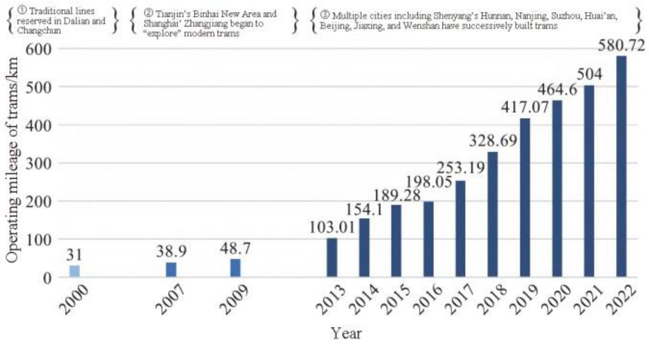

Fig. 2 Revival timeline of trams in the cities of the mainland of China

1.2 APM

APMs, also known as automatic guideway transit systems (AGTSs), are public transport systems with automatic driving and grade separation, mainly featuring miniaturization of trains. APMs were first developed by Westinghouse in the 1960s. Then, the technology was transferred to and finally mastered by Bombardier. Bombardier's APM systems have a total of 28 lines in operation worldwide. Most of these lines are used as internal transfer lines of airports, totaling 24 (85.7%), and a few of them are used for urban rail transit, totaling only 4 (14.3%).

Three APM lines have been built in the mainland of China. One is the APM of Beijing Capital International Airport, which is an internal line. The other two are urban rail transit lines, namely, Guangzhou's Metro APM Line (3.94 km) and Shanghai's Metro Pujiang Line (6.644 km), with a total mileage of only 10.584 km (see Fig. 3).

a Guangzhou's Metro APM Line b Shanghai's Metro Pujiang Line

Fig. 3 APM routes in China

1.3 Yunba

Yunba refers to a three-dimensional intelligent transport system with independent rights of way, created by BYD Co., Ltd., which debuted in 2017. Yunba is essentially a system with rubber-wheels and guideways, and its functions and parameters are similar to those of APM lines. Therefore, Yunba can be understood as a Chinese version of APM systems to some extent.

Few Yunba systems have been built and put into operation in China, including Bishan Yunba Demonstration Line in Chongqing (15.4 km) and Pingshan Yunba Line No.1 in Shenzhen (8.5 km). In addition, there is Dawangshan Yunba Sightseeing Line in Changsha (8.11 km) still in its trial stage. The above lines have a total mileage of only 32.01 km.

1.4 ART

ART refers to a system in which sensors are installed on a train (actually, a multi-section electric vehicle) to sense planned traffic lines on roads (namely, "virtual tracks") to ensure that the vehicle runs along these virtual tracks. What is worth discussing is that this kind of system may belong to road traffic, and calling it rail transit may not be suitable.

Jointly developed by multiple organizations such as CRRC Zhuzhou Electric Locomotive Research Institute Co., Ltd., ART debuted in Zhuzhou in 2017 as a demonstration line. By the end of 2022, cities with operating ART lines in China included Zhuzhou (14.6 km), Yibin (21.4 km), Wujiang (5.2 km), Harbin (18.9 km), Chengdu (12 km), and Xi'an Xixian New Area (6.5 km), with a total operating mileage of about 78.6 km. In addition, about 10 ART lines are under construction. As a new thing produced in China, ART is still at the stage of exploratory development.

2 Research of development status

2.1 Overall development

Fig. 4 summarizes operating mileage and proportions of the four main system modes of low-capacity urban rail transit. Trams account for the highest proportion (83%), serving as the absolute main force, followed by ART (11%), Yunba (5%) and APM (1%).

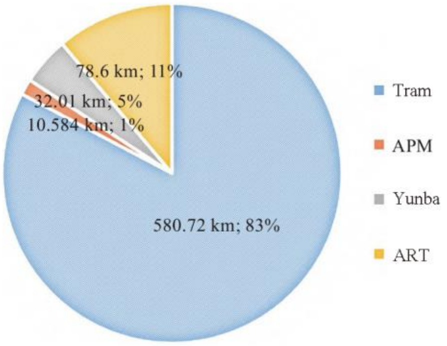

Fig. 4 Proportion of operating mileage of various low-capacity urban rail in China (as of December 2022)

In the last decade, the development of low-capacity urban rail transit has shown the overall trend and feature of "trams dominating, increased mileage, and emerging new system modes". However, there is also a gap between concept and practice during the development, which is embodied in the following aspects:

(1) Easier approval

After 2010, China began to construct tram systems on a large scale, with exploratory construction of such new systems as Yunba and ART, resulting in a rapid growth in low-capacity urban rail transit. However, research shows that low-capacity urban rail transit has mostly been built in new districts of big cities or in small and medium-sized cities. Such new districts are generally located on the peripheries of big cities, where high- and medium-capacity urban rail transit can hardly have a large coverage or be built on a large scale. Population and economic conditions of small and medium-sized cities fail to meet thresholds for subway and light-rail construction. Even if thresholds for approval are narrowly met, relevant construction plans are often put aside in the face of complex approval procedures and various uncertainties. As low-capacity urban rail transit is generally approved at a provincial or prefectural level, small and medium-sized cities tend to build low-capacity urban rail transit like trams, Yunba, and ART, with the use of their local independent decision-making power.

(2) Idealized functions

According to the analysis of routes of trams and ART, except for a few cities such as Huai'an and Jiaxing choosing relatively good downtown passenger-flow corridors, most of the rest cities choose wide roads and newly developed (or to-be-developed) areas along the lines. Reasons for making such choices are as follows. Firstly, it is easy to open new special lanes on wide roads, with less demolition and resettlement, less capital investment, and low social resistance (mainly from social vehicles). Secondly, it is expected that construction of trams and ART can promote the development along the lines, forming the TOD effect. However, in fact, travel speed of such low-capacity urban rail transit is of little difference from that of buses, and stations are generally located in the middle of roads, with a low degree of integration with the surroundings. As a result, low-capacity urban rail transit seriously lacks sufficient attraction to surrounding residents. It basically has no function of guiding urban development, and its TOD functions is often overestimated.

(3) Poorly evaluated effect

From the actual operation effects of established low-capacity urban rail transit, except that a few lines have slightly good passenger-flow benefits, lines in many cities suffer from poor passenger-flow benefits. The public generally has poor impressions on such rail transit, with its negative comments in this regard often seen on the Internet.

2.2 Functional aim

Functional aim and adaptability of low-capacity urban rail transit are analyzed according to different urban types.

(1）Big cities

Big cities generally have large-capacity urban rail transit, with low-capacity urban rail transit in the peripheral areas for transfer purposes to expand the scope of passenger-flow attraction, or in clusters of peripheral new towns to serve as internal backbone public-transport systems. Examples are trams lines of Nanjing's Hexi New Town, Shenzhen's Longhua District, Shanghai's Songjiang District, and Shenyang's Hunnan District, as well as Shanghai's Pujiang APM Line. This is basically consistent with functional aim of relevant lines in some cities in Europe and the United States.

In fact, the scale of China's big cities is much larger than that of foreign ones (especially big cities in Europe and the United States). As a result, residents have long travel distance, and are highly dependent on large-capacity urban rail transit in peak hours. Their jobs and residences are generally selected with closeness to subway stations as an important consideration. Thus, the demand for low-capacity urban rail transit as transfer lines is not strong. Urban rail transit networks in some peripheral areas have low density and insufficient service, indeed resulting in a demand for transfer. However, relevant operation experience of cities shows that low-capacity urban rail transit has low travel speeds and long departure intervals, hardly playing the role of connecting subways for transfer. Travel efficiency of transfer methods such as shared bicycles, private non-motorized vehicles, "P + R", taxis, and online car-hailing is often higher than that of low-capacity urban rail transit.

(2) Small and medium-sized cities

Small and medium-sized cities generally do not have subways. Instead, low-capacity urban rail transit is constructed as backbone systems of urban public transport, such as Huai'an and Jiaxing's trams and Yibin's ART. Such functional aim of low-capacity urban rail transit in China's small and medium-sized cities is similar to that in Europe's counterparts.

However, according to in-depth study, many cities in Europe build new systems by reconstructing their original low-capacity urban rail transit systems (mainly abandoned tram lines), and thus such new systems are of low cost. In addition, there are road sections and land development patterns that are suitable for original tram systems along these lines, as well as citizens' expectations for the return of trams. This results in a good implementation effect. Many cities in China need to start from scratch to thoroughly transform road sections. As tracks, signal devices, and vehicles in rail transit systems all need to be purchased, construction cost is obviously higher than that in cities with trams originally. In addition, according to the operation experience of China's cities that have low-capacity urban rail transit in operation, systems such as trams and ART fail to enjoy sufficient signal priority at intersections, with travel speeds almost the same as those of buses. As a result, they have no strong attraction to residents, and passengers make no high comments.

(3) Tourist cities (small towns)

Low-capacity urban rail transit planned and constructed in tourist cities (towns) generally functions not for daily travel of residents, but for serving tourists. Tourists' viewing experience is enhanced through the construction of low-capacity urban rail transit, such as some trams in Yunnan and Fujian, and Yunba in Changsha.

Such lines cost highly in construction and do not rely on residents' daily travel tickets to make up for their operating costs, thus facing huge financial pressure. Relevant construction parties should make plans for the return of capital in advance, such as raising ticket prices and incorporating them into scenic ticket packages to make up for operating costs. Alternately, a good government subsidy budget should be made, so that with the subsidy from governments, relatively cheap tickets can still be provided to serve and attract tourists to enhance their travel experience. Under the latter proposal, more economic benefits can be created for supporting industries such as accommodation and catering through longer stay of tourists in the scenic areas and cities, thereby compensating for the operational losses of low-capacity urban rail transit.

2.3 Operation environment

As motorization of Chinese cities is still at the stage of rapid rise, operating pressure of urban traffic is increasing. Traffic management in most cities is still mainly to ensure smooth flow of cars, and more extensive substantive measures have not yet been taken in terms of public transport priority [①]. Dedicated rights of way of public transport systems are not guaranteed. Some low-capacity urban rail transit uses dedicated lanes with no hard isolation from motor vehicles. This often leads to collisions in the case of social vehicles intruding into the dedicated lanes (see Fig. 5). Low-capacity urban rail transit does not enjoy absolute priority at intersections and its travel speed is only the same as that of buses. Thus, it has insufficient attraction to the public.

Fig. 5 The accident between ART and private cars

In addition, intrusion of pedestrians and cyclists also threatens driving safety of low-capacity urban rail transit. For example, pedestrians and non-motorized vehicles often ignore traffic lights and illegally pass through intersections, or cross roads where there are no zebra crossings (see Fig. 6). Low-capacity urban rail-transit vehicles have long carriages, and their drivers have longer observation distance. Thus, in order to prevent collisions with pedestrians and cyclists violating traffic regulations, low-capacity urban rail transit needs to be extra careful during travelling. This is the reason why its speed can hardly reach the design level and is often maintained at only about 15 $km \cdot h^{-1}$.

Fig. 6 Pedestrian intrusion into the track

[①] It refers to a comprehensive and systematic project for the government to completely reverse the traditional concept of "ensuring smooth transportation", fully implement the policy of public transport priority, form working mechanisms, prioritize the construction of public transport facilities, and cultivate citizens' awareness of travel with public transport.

From the above, there is still a certain gap between China's overall transportation development environment (such as the concept of public-transport priority and residents' awareness of traffic safety) and that of Europe and the United State. The operating environment for low-capacity urban rail transit in China fails to give full play to its advantages yet. Therefore, it is worth rethinking whether large-scale construction of low-capacity urban rail transit is suitable or not at this stage.

2.4 Operation effect

According to the comparison of passenger flow of some low-capacity urban rail-transit lines (see Table 1), only the APM line in the core area of Guangzhou and the Pujiang APM Line connecting Shanghai Metro Line No. 8 have relatively high passenger flow. Among the trams, only Shenzhen's Longhua Line and Beijing's Xijiao Line have relatively good passenger flow, while the rest lines mostly have a transport intensity of less than 1 000 passengers·km^{-1}·d^{-1}, many of which have a transport intensity of only 100–300 passengers·km^{-1}·d^{-1}. In terms of ART, Harbin's ART Line No. 1 had a transport intensity of only 90 passengers·km^{-1}·d^{-1} in the case of free ride during its trial operation. As can be seen, passenger transport intensity of China's low-capacity urban rail transit is badly low in most cases. Compared with the construction investment usually of CNY 100–300 million·km^{-1}, investment benefits are very poor. In contrast, the average transport intensity of trams in some European cities is about 4 000 passengers·km^{-1}·d^{-1} (or even over 12 000 passengers·km^{-1}·d^{-1} in the highest case), which is significantly higher than that in Chinese cities (see Fig. 7).

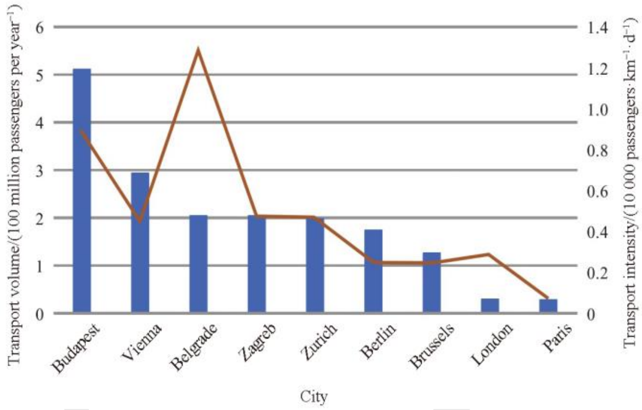

Fig. 7 Benefit statistics of tram passenger flow in Europe

Tab. 1 Statistics of passenger flow of low-capacity rail transit in China

City	System and line names	Mileage	Passenger flow (10 000 passengers·d^{-1})	Passenger transport intensity(10 000 passengers·km^{-1}·d^{-1})	Note
Shanghai	Zhangjiang Tram No. 1	9.8	0.1	0.010	Media coverage in February 2023
	Songjiang Tram Lines T1&T2	31.2	2.77	0.089	Data for December 2021
	APM (Metro Pujiang Line)	6.3	3.2	0.508	Annual data for 2021
Huai'an	Tram Line No. 1	20.07	1.59	0.079	Data for January–November 2022
Beijing	Xijiao Tram Line (Working days)	8.86	1.6	0.181	Benefits of passenger flow on holidays significantly higher than those on working days
	Xijiao Tram Line (Holidays)		4.5	0.508	
Shenzhen	Longhua Tram Demonstration Line	11.72	3.1	0.265	Data for November 2020
Foshan	Gaoming Modern Tram Demonstration Line	6.57	0.098	0.015	Annual data for 2020
Tianshui	Tram Demonstration Line (Phase I)	12.928	0.162	0.013	Data for January–November 2022
Sanya	Sanya Tram Demonstration Line	8.37	0.202	0.024	Data for January–November 2022
Honghe	Honghe Tram Demonstration Line	13.4	0.329	0.025	Data for October 2020
Wenshan	Puzhehei Tram	13.96	0.082	0.006	Data for January–November 2022
Jiaxing	Tram Line T1	13.8	0.412	0.030	Data for July–November 2022
Guangzhou	APM Line (Zhujiang New Town)	3.94	3.72	0.944	Annual data for 2021
Harbin	ART Line No. 1	18.2	0.173	0.009	Data for February–July 2022, free ride

2.5 Technical system modes

The development trend of low-capacity urban rail transit in China shows that cities often prefer to choose new system modes, blindly pursuing the so-called system mode innovation. Table 2 shows classification standards and applications of different types of trams.

Tab. 2 The application of various tram systems in China

Classification method			Technical description	City of tram application
By floor height			70% low-floor tram	Shenyang
			100% low-floor tram	Nanjing, Guangzhou, Suzhou, etc.
			Ultra-low-floor tram	
By travelling modes			With steel wheels and rails	Guangzhou, Zhuhai, Huai'an, Shanghai's Songjiang District, etc.
			With rubber wheels + guide rails	Tianjin's Binhai New area and Shanghai's Zhangjiang
By power-supply modes	Contact type		Overhead lines	Changchun, Dalian, etc.
	Noncontact type	Ground power supply	Alstom's APS systems	
			Bombardier's PRIMOVE systems	
			Ansaldo's Tram Wave	Zhuhai and Beijing's Xijiao
		Energy storage	Battery power supply	Nanjing
			Supercapacitor power supply	Guangzhou and Shenyang
			Hydrogen fuel-cell power supply	Foshan

The main tram manufacturers in the world are Bombardier, Alstom, Siemens, Caf, and Ansaldo. By technology introduction or cooperation, Chinese tram manufacturers have realized "localization" of most vehicles. However, due to independent development of trams in various regions, different cities have introduced technologies of different enterprises (two or three cities have introduced the technology of the same enterprise). Thus, almost every city needs to pay a lot of patent and technology fees to international giants of rail transit vehicles, but their technologies are actually of little difference. As a result, trams in various cities require exclusive customization, lacking mass production, with high maintenance costs.

Operating APM lines in the world are mostly used for internal transfer services of airports, and only four such lines are used for urban services. This to a certain extent indicates that application value of APM in urban public transport is not recognized by most cities. Similarly, it is also worth considering whether Yunba with similar features to APM has application value in cities.

ART enables electric buses to follow virtual tracks. Essentially, they have almost no difference from bus rapid transit (BRT), with ride experience almost the same as that of BRT. Especially, in the case of no signal priority at intersections, their operation efficiency is similar to that of buses on dedicated lanes. As a result, such systems fail to improve travel speed and attractiveness, with poor passenger-flow benefits.

Such so-called system mode innovation fails to bring about faster, more timely, and more convenient public transport services. It is of little significance, and inevitably suspected of sacrificing the essentials to the trifles.

2.6 Financial subsidy

As supply of government public goods is primarily undertaken by the urban public transport industry, this industry has a nature of public welfare in any country. This feature determines that public transport enterprises cannot completely be marketized, requiring the consideration of both economic and social benefits. Governments need to establish corresponding price control and subsidy models to find a balance between social-welfare maximization and capital efficiency, so as to not only realize public goals, but also encourage operating enterprises to improve efficiency. As a form of public transport, low-capacity urban rail transit also needs government subsidies if its ticket revenue fails to make up for construction and operating costs.

The total investment of Zhuhai Tram Line No. 1 was nearly CNY 2.4 billion. During the operation period from 2017 to 2020, the allocated financial subsidies exceeded CNY 170 million, with an average of more than CNY 44 million per year. In addition, the annual depreciation cost of the project was more than CNY 47 million. The two items alone lead to an average annual cost of more than CNY 91 million and an average daily cost of CNY 240 000. From the opening of the line in June 2017 to the end of 2020, the ticket revenue of trams totaled CNY 3.87 million, with an annual average of only more than CNY 1 million. The transportation cost per passenger was as high as about CNY 67, more than 13 times that of buses (CNY 5).

Shenyang Hunnan Modern Tram had suffered continuous losses from 2013 to 2019. The operating revenue–expenditure gap of opened lines totaled CNY 636 million, with an average annual revenue–expenditure gap of CNY 127 million, which caused a great financial burden to the government.

Other low-capacity urban rail transit also faces similar problems. Due to low intensity of passenger transport, ticket revenue is a drop in the bucket compared with high construction and operating costs. Generally lacking benign operating capacity, these operating companies mainly rely on government subsidies to maintain their operation and maintenance, which is not a long-term solution after all.

3 Development suggestions

3.1 Clarifying the development stage of domestic urban transportation, and objectively demonstrating the functional aim of low-capacity urban rail transit

Planning of low-capacity urban rail transit in Chinese cities generally takes functional aim, line network scale, and passenger flow benefits of such rail transit in foreign cities as benchmarks. On this basis, it is proposed that low-capacity urban rail transit should also be added in urban public transport systems. In fact, traffic development of different cities has its own characteristics, and foreign experience may not be suitable for respective national and city conditions.

Taking renascent trams in Europe as an example. Many European cities have a long history of tram networks, with natural advantages of reviving trams. With the increasing traffic congestion and deteriorating environment in European cities, decision-makers and citizens have a common demand for the return of green transportation and trams. This lays a good foundation for the revival of trams.

On the contrary, many Chinese cities do not have such a hardware basis, let alone reaching a broad consensus on encouraging development of public transport and restraining that of cars. Therefore, on the basis of fully learning from development experience of foreign low-capacity urban rail transit, we should analyze adaptability of low-capacity urban rail transit such as trams, APM, Yunba and ART in Chinese cities to avoid counterproductive effect.

As a suggestion, Chinese cities should first study their own transport development stages and environment and analyze adaptability of low-capacity urban rail transit from the perspective of functional aim to make correct decisions on local feasibility of such rail transit. Planning of low-capacity urban rail-transit lines and formulation of construction plans can be initiated after in-depth consideration and research.

3.2 Avoiding blindly pursuing diverse system modes, and focusing on improving the efficiency of public transportation

Urban public transport in China is facing direct confrontation and continuous competition with the automobile traffic featuring a growing number of private cars. From relevant research, in the case of the same departure points and destinations, if travel time of public transport is much longer than that of cars, preference of citizens to public transport in choosing transport means will be reduced greatly [1] (see Fig. 8).

The reason why citizens have relatively high dependency on subway travel is that subways enjoy a completely independent right of way and can provide faster travel than road traffic can during peak hours. Time consumption of citizens taking subways in commuting hours is basically predictable and controllable, while that of car travel is not the case during peak hours.

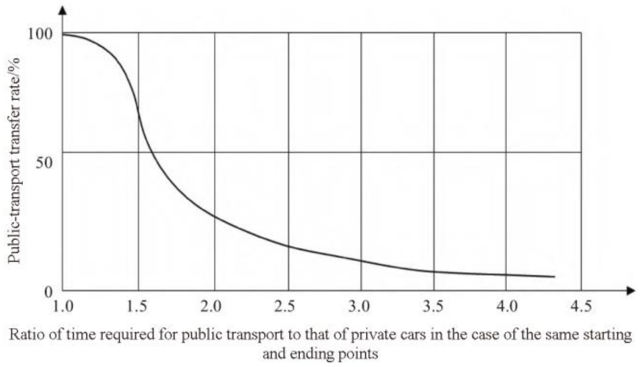

Fig. 8 The transfer curve of passenger flow competition between public transport and private cars

Cities with the intention of constructing low-capacity urban rail transit should first pragmatically solve the outstanding problem of unobvious competitive advantages of inter-cluster public transport, instead of seeking system mode innovation. It is suggested that inter-cluster trunk BRT should be first opened by setting up dedicated lanes and giving signal priority at intersections, so as to reduce time consumption of trunk buses between clusters to a level close to that of cars. In this way, we can cultivate bus passenger flow on the main inter-cluster channels in cities, so as to reverse citizens' over-dependence on private cars.

As proven by facts, as long as buses have fully independent rights of way on their dedicated lanes, with signal priority given at intersections and short departure interval, public vehicles such as backbone buses and BRT can outperform low-capacity urban rail transit. For example, Guangzhou BRT and Xiamen BRT (with transport intensity being at 2 500–3 000 passengers$\cdot$km$^{-1}\cdot$d^{-1}) both give full play to their characteristics of fast travel and high departure frequency, thus successfully winning the favor of citizens. As a result, their passenger transport intensity is significantly higher than that of most low-capacity urban rail transit lines (see Fig. 9).

a Guangzhou BRT

b Xiamen BRT

Fig. 9 Successful BRT systems in China

In addition, compared with low-capacity urban rail transit, backbone buses or BRT systems with dedicated lanes and signal priority at intersections have a small scale of infrastructure transformation, low overall costs, and flexible line settings. Moreover, their line directions and station settings can be adjusted timely according to actual operation situations or subsequent rail-transit construction needs, with relatively low adjustment costs, without a waste of resources. For example, Changzhou and Urumqi first built BRT systems on the main passenger flow corridors to cultivate passenger flow and then planned to build subways after steady growth of passenger flow, thus realizing smooth transition of bus passenger flow. This can be taken as reference by other cities in China.

3.3 Carefully studying the investment benefits of the system, and strictly approving related construction projects

In 2003, Circular of the General Office of the State Council on Strengthening the Management of Construction of Urban Rapid Rail Transit (No. 81 [2003]) was issued. It stipulates basic thresholds for cities to apply for constructing subways and light rails, but with no provisions relating to low-capacity urban rail transit. In July 2018, Opinions of the General Office of the State Council on Further Strengthening the Management of Planning and Construction of Urban Rail Transit (No. 52 [2018]) were issued. Only some provisions were added to make it clear that tram construction should be approved by provincial development and reform departments. However, application and approval thresholds for tram construction were still not stipulated, and there were no relevant requirements and instructions for other low-capacity urban rail-transit systems.

In 2021, relevant departments issued guidance, finally putting forward thresholds for constructing low-capacity urban rail-transit systems. The main points are as follows: (1) In terms of functional aim, low-capacity urban rail transit is urban rail transit that serves urban areas, peripheral clusters, industrial parks, tourist scenic spots, and other areas with unidirectional maximum cross-section flow of 5 000–10 000 passengers in peak hours. (2) Project costs and passenger flow are strictly controlled. In principle, direct project investment (construction and vehicle purchase costs) of low-capacity urban rail transit shall not exceed CNY 100 million·km^{-1}, and initial flow shall not be less than 1 000 passengers·km^{-1}·d^{-1}.

The requirement of unidirectional maximum cross-section passenger flow in peak hours is reasonable, matching transport capacity of low-capacity urban rail transit. However, the unidirectional cross-section flow of the main bus passenger flow corridors in many cities can hardly reach the threshold of 5 000–10 000 passengers during peak hours. Even if this threshold is reached by passenger flow corridors of a few cities, these cities often consider constructing large- and medium-capacity urban rail transit, instead of planning to build low-capacity urban rail transit. In addition, operation data of many cities with operating trams indicate that daily unidirectional maximum cross-section passenger flow is even less than 5 000. Let us take Shanghai's Songjiang Tram as an example. As the internal backbone public transport of Songjiang New City, one of the five major new cities in Shanghai, the tram narrowly maintained the unidirectional maximum cross-section flow at about 5 000 passengers per day in the third year (2021) after its opening.

It is also difficult to meet the requirement that project investment of low-capacity urban rail transit should not exceed CNY 100 million·km^{-1}. Taking trams as an example (see Fig. 10), except Shanghai's Zhangjiang Tram Line No. 1 and Shenyang's Hunnan Tram Lines (No. 1–No. 6), which were built earlier with investment lower than this index, trams in the other cities basically have construction investment higher than this index. Specifically, the highest investment was about CNY 300 million·km^{-1}, which is close to the construction cost of light rails. According to the data reported by the media in Harbin and Yibin, ART construction costs in the two cities can meet this index. As for APM lines and Yunba, they require much higher construction costs due to their overhead arrangement. Therefore, it seems that only ART can meet the index of project investment.

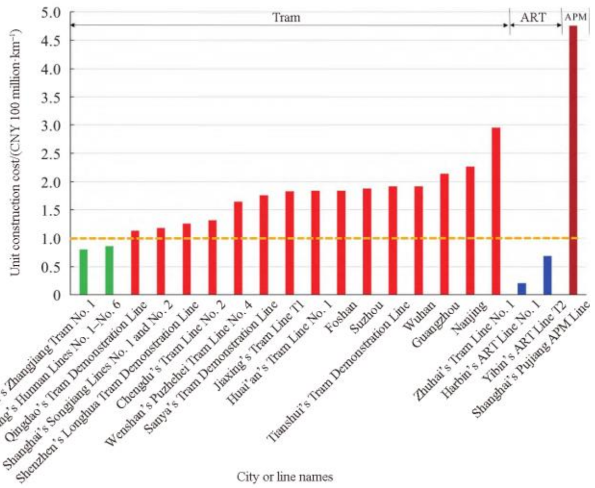

Fig. 10 Construction cost of low-capacity rail of some cities in China

Data sources: it is prepared based on network data and media reports. Note: data for Foshan, Suzhou, Wuhan, Guangzhou, and Nanjing are average values of multiple lines.

For this reason, it is necessary to further improve thresholds for constructing low-capacity urban rail transit. For example, the threshold of investment costs less than CNY 100 million·km^{-1} can only be met by a few system modes. Compared with such high investment, the index of transport intensity of 1 000 passengers·km^{-1}·d^{-1} is actually low. Therefore, it is suggested that investment benefits of low-capacity urban rail transit should be fully investigated and objectively evaluated. If low passenger-flow benefits and huge financial subsidies are common and cannot be avoided at this stage, relevant examination and approval procedures should be suspended. Instead, backbone buses and BRT with efficient use of bus lanes, guaranteed traveling speed, and short departure intervals should be developed, which will be more practical.

4 Conclusions

This paper summarizes the general development situation of low-capacity urban rail transit, makes comprehensive study, evaluation, and examination of its development adaptability, and analyzes the objective factors and reasons for its unsatisfactory development. On this basis, suggestions are proposed as follows. During the development of low-capacity urban rail transit, we should strengthen the research on functional aim and make prudent decisions, fully evaluate investment benefits of projects and strictly examine relevant construction projects for approval, and avoid blindly pursuing mode innovation of low-capacity urban rail transit. Moreover, efforts should be made to improve travel efficiency of various public transport means including and not limited to low-capacity urban rail transit to enhance residents' trust and stickiness to public transport, so as to implement the strategy of public transport priority.

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