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# *Melbourne Multilayer Public Transport System Research*

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***Abstract:*** From the perspective of Melbourne's multilayer public transport system, the status, functions and relationships of Melbourne trams, suburban railways and buses are sorted out. Taking the public transport in operation in Melbourne as an empirical research object, this paper rationally analyzes the development prospect of Melbourne's multilayer public transport in China and compares the advantages and disadvantages of Melbourne public transport system and China's public transport system. It is concluded that the network form, function and hierarchical relationship of Melbourne's public transport can better adapt to the stage and requirements of Melbourne's city development. It has the effect of optimizing the city traffic networks and complementing city planning and development and plays a role in building Melbourne's three-dimensional and complete multilayer-city transport system, easing the urban center population and alleviating city expansion. It is analogized that both Melbourne public transport and China's public transport system have the advantages of structural rail transit loop, radial multi-level railway system and complementary functions of various public transport systems, but there are differences in the same, and their respective shortcomings need to be improved.

## 1. Introduction

In the middle of the 19th century, Robert Hoddle proposed to build a railway between Melbourne and Hobson Bay, and the public transportation system began to be gradually established. With the development of the city, after several network planning revisions and more than 100 years of construction, a complete and highly diversified public transport system has been formed from scratch, and it has the world's largest tram system. Melbourne's public transport system is mainly based on rails, supplemented by buses, and relies on traffic to guide the outward expansion of space. At the same time, on the existing multilayer public transport system, continuous improvement has been made to accelerate spatial development and promote city structure transformation. Similar to Melbourne, China's metropolises are in the critical period of changing from a single-center city structure to a multi-center city structure and are committed to optimizing multilayer public transport systems. By the end of 2022, China's bus lanes reached 19,900 kilometers, and the operating mileage of city rail transit reached 10,287.98 kilometers. The scale of city transportation construction has been comparable to that of global cities. Therefore, through the in-depth study of the characteristics and functions of Melbourne's multilayer public transportation system composed

of trams, suburban railways and buses, we will further understand the functional positioning and spatial relationship of transportation at all levels in the public transportation system, and compare the advantages and disadvantages of Melbourne's public transportation system and China's public transportation system. This will provide direction for the two countries to improve their public transportation systems.

## 2. Melbourne City Structure and Public Transport System

### 2.1 Single-center City Structure-Multi-center City Structure

Melbourne is located on the eastern coast of Australia and is the largest city in Australia and the capital of Victoria. Since Melbourne was granted city status by Queen Victoria of the UK in 1847, it has gone through the 19th-century gold rush, the post-war prosperity of the 1950s, and the third period of rapid population growth, evolving into an international metropolis with over 5 million people, covering nearly 9000 km², and a diverse culture [1]. For several years, Melbourne has been rated as one of the most livable cities in the world by the International Livability Index.

Melbourne's city planning began with Robert Hoddle's Hoddle Grid in 1837, as shown in Figure 1, which laid the foundation for Melbourne's public transport system and city development structure over the past 180 years - the single-center city structure. Melbourne is a typical single-center city structure, with highly connected and dense suburbs surrounding the original "walking city" center of Melbourne, and vast scattered residential areas collectively forming the city. These areas are connected by a railway network or tram network built by the colonial government [2]. At the beginning of the 20th century, with the continuous growth of Melbourne's economy and population, as well as the expansion of the city's built-up area, a variant of the garden city—peri-urban areas became the dominant planning form in Melbourne. It had little impact at the metropolitan level but influenced the layout of the metropolitan fringe areas and village suburban parcels. In 1917, Australia held a conference in Adelaide with the theme of "Promoting the universal education and public understanding of the science and principles of city planning, garden cities, and housing." Since then, the "Canberra" [3] model began to emerge and had a profound impact on the establishment of the multilayer public transportation system in Melbourne. Its main feature is that the city radiates circularly from the city center outwards, with the suburbs and surrounding countryside adjacent. Over the following century, Melbourne, through the large-scale development of suburbs and organization of transportation networks, has built a single-centered city structure based on a convenient public transportation system. In the 21st century, Melbourne introduced the "Melbourne 2050" plan, guiding the city's development towards a multi-centric direction. Key construction focuses include planning ten major urban centers, developing a multi-dimensional transportation network, and constructing nationally important employment cluster zones [4]. In Melbourne, the construction of Australia's largest ever public transportation project—Suburban Rail Loop, is reshaping the city's development for the next few decades, marking the official advancement of the multi-centric city structure [5].


(Source: Victorian Public Record Office VPRS 8168/P0002, SYDNEY M8)

Figure 1: Road network and parcel mapping of Melbourne town drawn by Robert Hoddle in 1837

## 2.2 Multilayer Public Transportation System

Since the first steam train in Australia traveled from Flinders Street to PortMelbourne in 1854, Melbourne's public transportation system has been in development for over a century. The social development during this period, along with the coordination between city spaces and public transportation, led to the formation of today's typical single-centered city structure and its corresponding multilayer, multi-system, and multi-mode public transportation network, as shown in Table 1. Melbourne's public transportation system, as shown in Figure 2, is mainly divided into three levels: the first level is tramways as the primary mode of public transport, the second level comprises suburban railways complementing the tramways, and the third level is filled by buses to bridge the gaps left by Melbourne's rail transit.

Table 1: A list of the functional hierarchy of Melbourne's public transport system

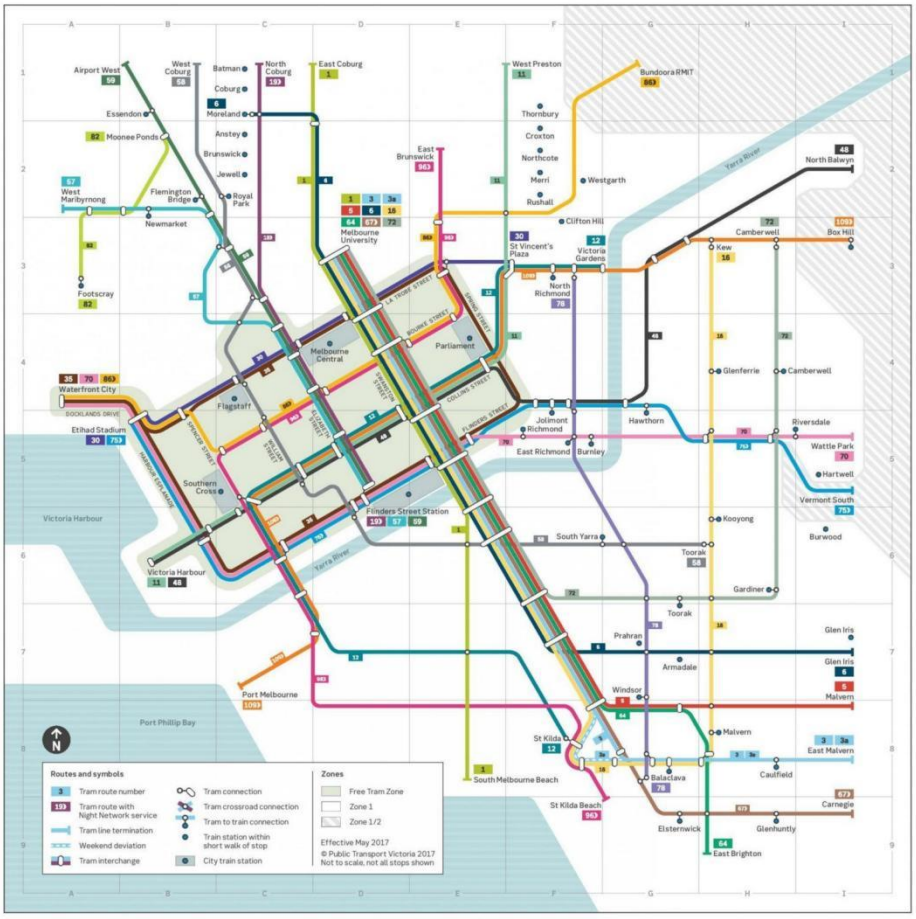
| status hierarchy | Service hierarchy | Function hierarchy | category | Service area | Vehicles (column) | line operate (unit) | total line (km) | Total site (piece) |
|---|---|---|---|---|---|---|---|---|
| Main Traffic | Tramway | Urban Services | Tramway<br>Free City Circle Tram | Melbourne central area and surrounding areas | 493 | 24 | 250 | 1763 |
| Important Supplement | Suburban Railway | Suburban Services | Metro Train<br>V/Line Train | Melbourne inner city and outer areas | 226 | 15 | 998 | 222 |
| Secondary Additions | Bus | City Services | Bus<br>Smart Bus<br>Night Long-distance Bus | Within Melbourne, mainly in the outer suburbs | / | 346 | / | / |


Figure 2: Map of the current state of Melbourne's multilayer public transport system

When Melbourne's tramway system was initially constructed in 1884 as a critical backbone system for inner-city public transportation, it was extensively developed. Presently, Melbourne's tramway system, as shown in Figure 3, is the largest in the world, covering a total of 250km of double tracks, 1763 tram stops, 493 trams, and 24 operational routes [6], while also featuring a free city circle tram. Based on the existing Hoddle Grid road network, Melbourne's tramways form a checkerboard layout in the city center, with an overall radial pattern extending from the central loop to the periphery [7], reinforcing Melbourne's single-centered city structure. As Melbourne's suburban areas matured, the demand for passenger flow connecting the outskirts with the urban center gradually increased. Starting from the Victorian-era Octopus Act in the 1880s, the Melbourne Parliament successively passed two acts authorizing the construction of 23 and 66 new routes, establishing train systems in most of Melbourne's northern, eastern, and southeastern suburbs, roughly matching today's scope, as shown in Figure 4. In the 1970s, to further alleviate population congestion in the urban center and strengthen regional connections between Melbourne's major railway hubs—Flinders Street Station and the Victoria State Regional Railway Hub—Southern Cross Station, Melbourne began the construction of the CBD underground loop railway. A well-developed radial suburban rail system radiating from Melbourne City Center and Flinders Street Station towards the surrounding areas, as shown in Figure 5, gradually expanded. This system covers areas extending far beyond the city fringe, comprising 11 main lines and 4 branch lines with a total length of 998 kilometers. This underground loop + radial rail network structure has cultivated a stable passenger flow for Melbourne's single-center city structure and promoted the integration of suburban development. As the final component of Melbourne's public transportation system, buses, with a total of over 300 routes, predominantly serve corridors without rail transport services.

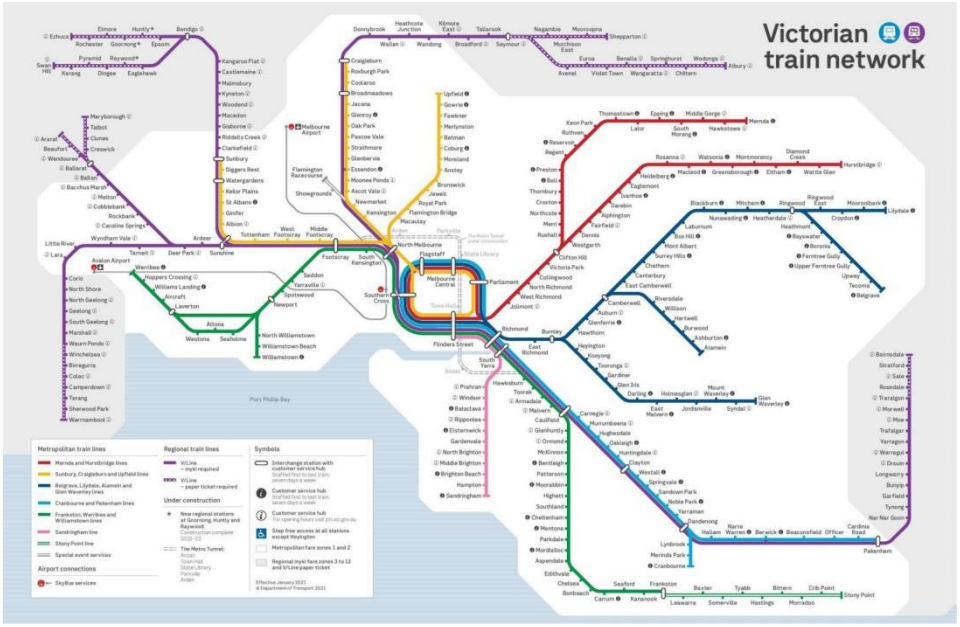

(Source: MelbourneMap360 [8])

Figure 3: Melbourne Tramway System Roadmap.




(Source: Melbourne & Suburban Railway Co. - Victorian Railways, Museum Victoria, Australia. museumsvictoria.com.au)

Figure 4: Map of Melbourne's Victorian railway network in the era of the Octopus Bill.




(Source: MelbourneMap360 ⁹)

Figure 5: Melbourne suburban railway system route map.

## 3. Characteristics of the Melbourne Multilayer Public Transport System

### 3.1 Radiation + A Ring Track Network

Analyzing its network structure, Melbourne's rail transit system primarily consists of radial routes, with trams forming a circular network in the city center. The suburban railway radiates outward mainly from Flinders Street Station and Southern Cross Station, creating a radial network providing intra-city, suburban, and intercity transportation services. The suburban railway's “radial” lines extend up to 302 km, further dispersing the population outward, diffusing the functions of the urban center, and balancing development across various regions. The V/Line routes departing from Southern Cross Station facilitate commutes between Melbourne and different cities across Victoria. Melbourne's “radial” rail network is flexibly configured according to the functional positioning of different suburban centers and passenger flow requirements. The passenger flow direction extends outward from the center, enhancing the development level of rail transit in the inner and outer suburbs. These networks also effectively connect with trams, laying the foundation for promoting Melbourne’s Multi-center city structure [8]. Tram Route 35 forms a circular network in Melbourne City Centre, as shown in Figure 6, balancing the passenger flow of the radial rail network, further consolidating Melbourne’s single-center city structure, and together with suburban railways, constituting the main components of Melbourne's rail transit system.

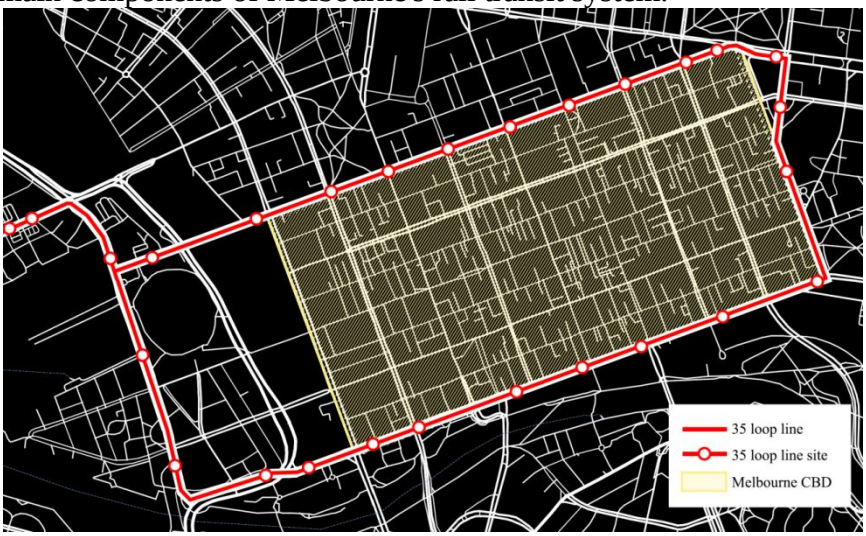
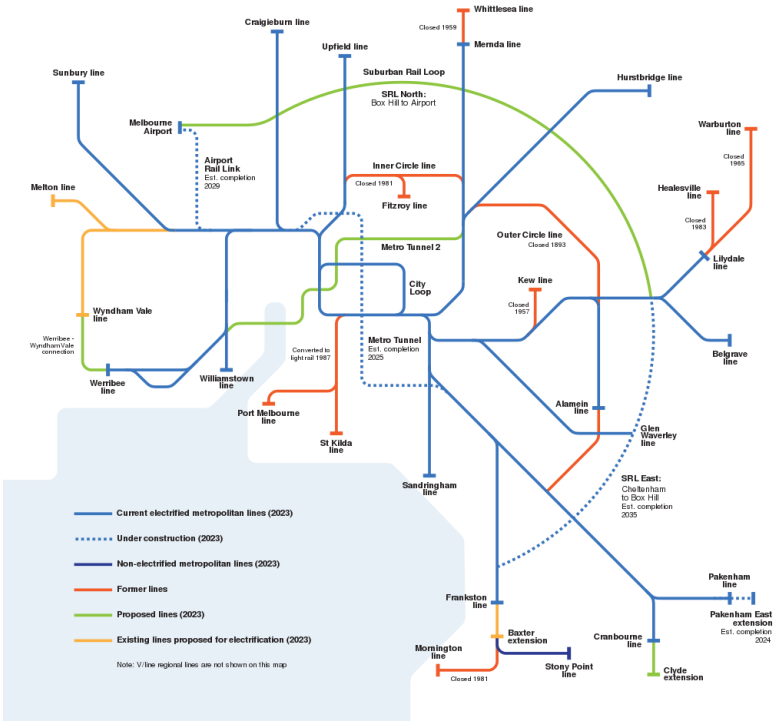



Figure 6: Melbourne free City Circle Tram route map

### 3.2 The Symbiosis of Rail Transit Systems at All Levels

The Melbourne tram line was planned in the 1880s, during which time, to enhance the function of the Melbourne City Centre as a single center, trams covered the entire city center and extended into the suburbs. At the beginning of the 20th century, under the background of accelerating the process of global economic integration, the introduction of the concept of an idyllic city and the formation of the “Canberra” model, Melbourne began to accelerate outward expansion, emphasizing the balanced development and cooperation of different levels of regions, especially suburbs, in city functions, spatial layout and location relationship. Therefore, based on the existing tram, the connection between Melbourne City Center and suburbs, Melbourne and other cities in Victoria was strengthened by extending the radial traffic network and building The City Loop, which stabilized Melbourne's single-center city spatial structure based on the convenient rail transit system. This will lay the foundation for the transition into a multi-center city structure. The

construction of the bus is to supplement the shortcomings of the existing rail transit lines, running between the city, suburbs and inter-city. In 2018, Melbourne's city population reached 2 million. To cope with the increasing population and alleviate the road traffic pressure caused by the lack of rapid transit in the outer suburbs, the Victorian government announced the implementation of the Suburban Rail Loop plan, as shown in Figure 7. Through the three super transport hubs of Clayton, Broadmeadows and Sunshine, almost all of Melbourne's existing suburban train lines are connected in series, and the traffic-oriented multi-center city structure is better constructed. At the same time, the MetroTunnel is built to dredge the city ring line, so that more trains can frequently cross the Melbourne City Centre. From the perspective of the development of the whole public transport system, Melbourne strictly practices the concept of TOD (Transit Oriented Development), develops the rail transit system with traffic orientation [9], seizes the opportunity for construction, constantly improves the original rail transit system, realizes the symbiosis of rail transit systems at all levels [10], and meets the needs of consolidating the single-center city structure and developing the multi-center city structure in the development process of Melbourne.




(Source: Wikipedia)

Figure 7: SRL loop planning map.

### 3.3 The Comprehensive Transportation System of the Outer, Middle and Suburban Areas

From the perspective of functional positioning, Melbourne's various transportation lines are not independently operating systems, but present an integrated public transport system that is far from the bus system, medium for the suburban railway system, and near the tram system. As the most important public transport system in Melbourne, the tram has a complete network of lines throughout the entire city area of Melbourne. As a supplementary network, the suburban railway system mainly focuses on the radial corridor connecting the city center and the suburbs, which can effectively connect the tram traffic system to improve the entire Melbourne rail transit network. For example, The City Loop has 16 suburban lines leading to the periphery of the city. There are five stations in the ring line, located in Melbourne City Center, namely: Southern Cross Station,

Flagstaff Station, Melbourne Central Station, Parliament Station and Flinders Street Station. The City Loop is almost connected to all trams, providing sufficient passenger flow feeding for tram lines, ensuring the scale of passenger flow and achieving certain economic benefits. The bus is the second supplement to the suburban railway. It mainly serves the outer suburbs and undertakes the local contact between some trams and the railway network.

## 4. Compared with the Advantages and Disadvantages of Melbourne and China's Public Transport System

### 4.1 CityRail Transit Loop

Melbourne's rail transit network presents a radial ring, in which the city rail transit ring line is a structural ring line [11], which is an important part of the public transport system. Any point on the ring can reach another point on the ring without transfer, effectively relieving the passenger flow brought by the ray, and stabilizing the single-center city structure. The rail transit network of most major cities in China also has a structural ring line. Melbourne's ring network is mainly surrounded by trams around Melbourne City Center, including a checkerboard network. Although it greatly adapts to the single-center city structure, trams do not have absolute right of way. In addition, the road resources in the city center are relatively tight, the road traffic organization is complex, and the congestion phenomenon is serious, which will lead to the slow speed of trams and is not conducive to easing city traffic. However, China's metropolitan ring line fails to keep up with city development in time, resulting in the line network not fully covering crowded areas, and the equilibrium effect on ray passenger flow is limited. For example, the function of the “ring” in the online network of the Shanghai metro ring line is relatively weak. As a loop line, Line 4 fails to give full play to its loop function. The existing ray congestion areas are mainly concentrated in 1-5 stations outside the loop line, and the large-section passenger flow of the ray cannot be effectively relieved through the loop line, resulting in the hub station in the core area of the central city facing huge passenger flow pressure. The top 30 stations in the daily passenger flow bear 29 % of the total network traffic, of which 53 % of the stations are located within the loop line of Line 4 ( including the loop line ), as shown in Table 2. The average daily passenger flow of the whole network accounts for 54.1 %, while the proportion of passenger flow of Line 4 as the loop line is only 5.6 %, which is the same as that of Line 7, Line 12 and Line 13, as shown in Figure 8.The proportion of daily average passenger flow does not match its functional magnitude, and the loop line function is not realized.

Table 2: Shanghai metro station daily average access ranking table

| Billing | Position | Name | Passenger flow ( 10,000 person-times ) |
|---|---|---|---|
| 01 | Outside the fourth ring Road | Hongqiao Railway Station | 22.7 |
| 02 | Inside the fourth ring Road | People's Square | 19.7 |
| 03 | Onthe fourth ring Road | Shanghai Railway Station | 17.8 |
| 04 | Outside the fourth ring Road | East Nanjing Road | 15.9 |
| 05 | Inside the fourth ring Road | Jing'an Temple | 15.8 |
| 06 | Outside the fourth ring Road | Lujiazui | 15.2 |
| 07 | Inside the fourth ring | Xujiahui | 15.0 |

| | | | |
|---|---|---|---|
| | Road | | |
| 08 | Inside the fourth ring Road | West Nanjing Road | 14.4 |
| 09 | Inside the fourth ring Road | South Shaanxi Road | 11.2 |
| 10 | Onthe fourth ring Road | Zhongshan Park | 10.4 |
| 11 | Onthe fourth ring Road | Century Avenue | 10.4 |
| 12 | Outside the fourth ring Road | Loushanguan Road | 9.0 |
| 13 | Outside the fourth ring Road | Shanghai South Railway Station | 9.0 |
| 14 | Inside the fourth ring Road | Yuyuan Garden | 8.6 |
| 15 | Outside the fourth ring Road | Jiuting | 8.1 |
| 16 | Outside the fourth ring Road | Xinzhuang | 7.6 |
| 17 | Outside the fourth ring Road | Songhong Road | 7.5 |
| 18 | Outside the fourth ring Road | Sijing | 7.4 |
| 19 | Inside the fourth ring Road | Jiangsu Road | 7.0 |
| 20 | Inside the fourth ring Road | Dapuqiao | 6.7 |
| 21 | Outside the fourth ring Road | Caohejing Hi-Tech Park | 6.6 |
| 22 | Onthe fourth ring Road | Yishan Road | 6.6 |
| 23 | Outside the fourth ring Road | Oriental Sports Center | 6.5 |
| 24 | Outsidethe fourth ring Road | Qibao | 6.4 |
| 25 | Insidethe fourth ring Road | Jinshajiang Road | 6.3 |
| 26 | Outsidethe fourth ring Road | Lianhua | 6.3 |
| 27 | Inside the fourth ring Road | Shangcheng Road | 6.3 |
| 28 | Insidethe fourth ring Road | South Huangpi | 6.3 |
| 29 | Insidethe fourth ring Road | Pudian Road | 6.1 |
| 30 | Outsidethe fourth ring Road | Guilin Road | 6.0 |

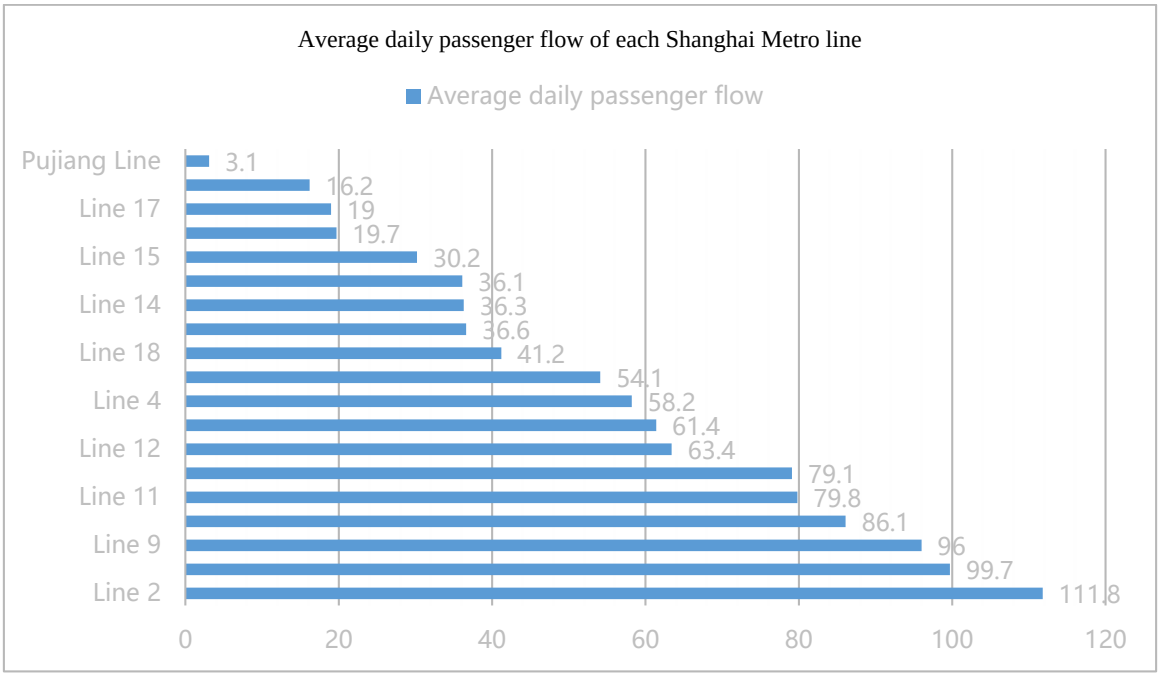



Figure 8: Average daily passenger flow of each shanghai metro line

## 4.2 Radial Multilayer Railway System

The city structure of Melbourne and China's metropolises is in the early stage of transition from single-center to multi-center. The radial railway system is the main support point of spatial organization. It is roughly divided into three levels: urban line, city line and local line, as shown in Figure 9, which leads to the reconstruction of regional space. The Melbourne railway system covers almost the entire Melbourne region and is mainly divided into Metro trains serving the suburbs, V / Line intercity trains serving the outer suburbs, and long-distance train services connecting states. The Metro train is a commuter rail system radiating outward from the Flinders Street station. The V / Line train line is to strengthen the connection between the outer suburbs of Melbourne and Melbourne City Centre, starting from the Southern Cross Station, connecting the five major regional cities of Ballarat, Bendigo, Geelong, Seymour and Traralgon, laying the foundation for the transformation of city structure. At the same time, Southern Cross Station also set up an interstate train transfer station, which can lead to Sydney, the capital of New South Wales, and Adelaide, the capital of South Australia, becoming an interstate transportation hub. As the largest city in China, Shanghai's railway system is undergoing a period of rapid transformation and development. It is about to form a radial multilayer railway system similar to Melbourne, as shown in Figure 10. It is mainly divided into active subways in the city center and concentrated construction areas, fast rail transit connecting the five new towns, and intercity railways connecting provinces and cities. The functions correspond to Melbourne's Metro trains, V / Line intercity trains and long-distance train services. Shanghai already has a radial subway transportation network with large transfer hubs such as People's Square, Century Avenue, Xujiahui and Longyang Road as the core [12]. To continue to rely on the railway system to guide the outward expansion of space, Shanghai plans to use rapid rail transit to support the spatial development of the five new cities of Jiading, Qingpu, Songjiang, Fengxian and Nanhui based on railway traffic in the centralized built-up area, and to move towards a multi-center city structure. The development of the intercity railway enables Shanghai to promote non-core functions to the surrounding cities, establish a “1 + 8” Shanghai metropolitan area [13], and promote city expansion.

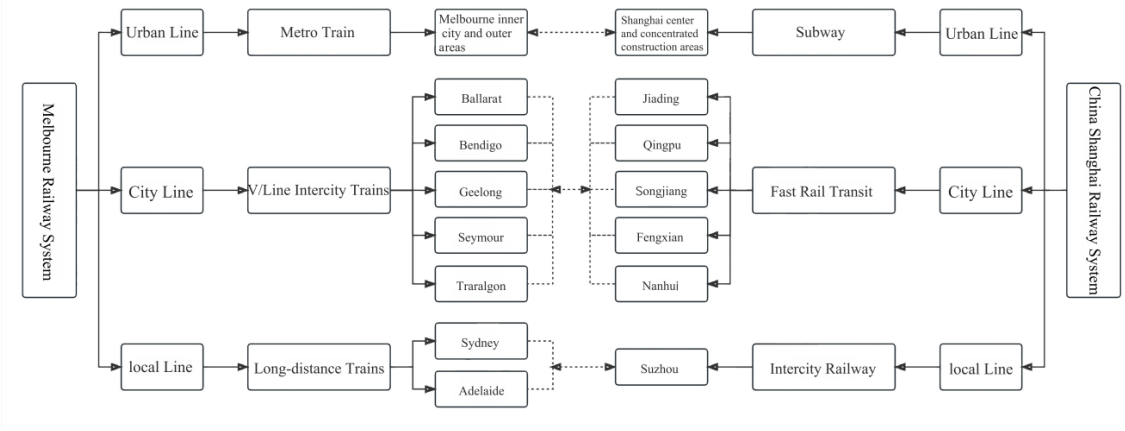



Figure 9: Comparison of Melbourne, China (Shanghai) railway systems

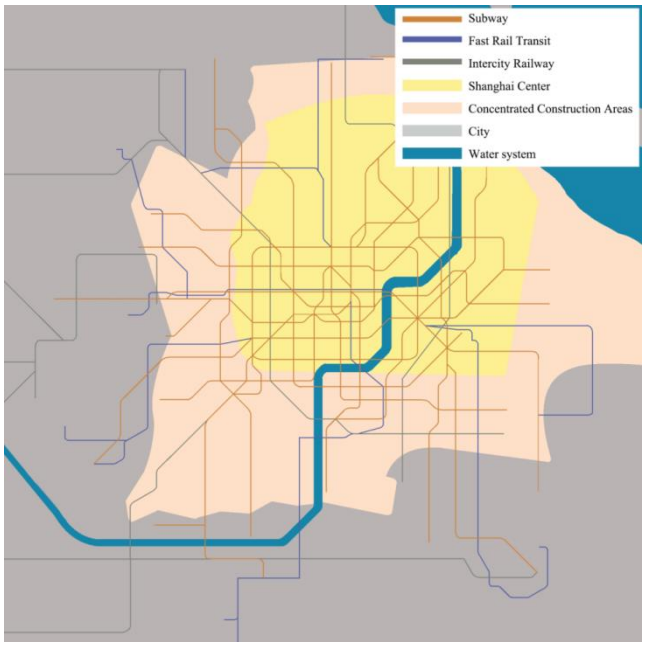



Figure 10: Shanghai railway system route map

## 4.3 Features of Complementary Development into a Multilayer Public Transport System

Melbourne's multilayer public transport system is mainly composed of trams, suburban railways and buses. The service scope of each system is divided and complements each other. As the most important means of transportation in the city, trams operate in and around the city center; as a supplement to the tram, the suburban railway is the link between the city center and the suburbs. The bus is the last supplement, mainly active in the outer suburbs without rail transit. China is in the golden period of building a multilayer public transport system, mainly composed of subway, suburban railway and bus. For example, Shanghai's subway network, as the core network of the public transport system, mainly serves the city center and the centralized construction area; the fast-track railway under construction is used as a supplement to quickly connect the city center with the five major new towns in the suburbs; buses shuttle in the city, flexible through the various places in Shanghai. It can be seen that the public transport systems in Melbourne and Shanghai are mainly composed of three systems. The service scope of the three systems extends from near, middle and far to the outside, with clear division, mutual complement and common development,

and finally forms a multilayer public transport system. However, the composition of Shanghai's multilayer public transport system has undergone great changes. Tram was the main public transport in Shanghai during the period of the Republic of China, but it was completely dismantled in 1975. It was not until the opening of Songjiang Tram in 2019 that Shanghai regained its tram system. Therefore, Shanghai has not fully complied with the principle of symbiosis of public transport systems at all levels. This large-scale demolition is not conducive to the integration of transportation resources and is contrary to the characteristics of complementary development of multilayer public transport systems.

## 5. Conclusion

After more than a hundred years of development, Melbourne has established a complete multilayer public transport system based on trams, suburban railways and buses. Its network form, construction work and network function can well adapt to the needs of Melbourne's city structure transformation coding [14], optimize the city traffic system and promote city planning and development. At present, most of China's metropolises are in the process of transforming from single-center city structure to multi-center city structure, which is similar to the development background and construction work of Melbourne's public transport system. By further exploring the development experience of Melbourne's public transport system, it is rationally analyzed and compared that Melbourne and China's public transport system have the same advantages in traffic network and system characteristics, but they have their own problems, which provides a reference direction for the subsequent development of public transport systems in the two countries.

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