Citation: LIU Tao, PAN Haixiao. Park and Ride Practice in Shanghai [J]. Urban Transport of China, 2020 (6): 45–49, 74.

Park and Ride Practice in Shanghai

LIU Tao[1,2], PAN Haixiao[1]

1. College of Architecture and Urban Planning, Tongji University, Shanghai 200092, China;
2. Shanghai Urban-Rural Construction and Transportation Development Research Institute, Shanghai 200040, China

Abstract: Since the building of two park and ride (P&R) parking lots on Songhong Road and Hongmei Road in 2009, more than thirty P&R parking lots have been formed in Shanghai. The usage of these P&R parking lots is different, and the social evaluation is also different. In order to guide the planning of P&R parking lot, and reduce the uncertainty of planning and usage, this paper summarizes the planning and management of P&R parking lot in Shanghai. Qualitative, and quantitative methods, such as questionnaire, case analysis and model analysis are used to analyze the functionalities of P&R part lot, station connection and external effects from the perspective of the origin of vehicles, connecting transportation service and mode change. Finally, the paper provides suggestions on P&R parking lots planning. The station type and location should be differentiated based on parking lot function. The planning should be integrated with other connecting travel modes to form an integrated connecting system. It is necessary to measure the external effect comprehensively, to build and share with other parking lots, and to consider function transformation of future land use. **DOI:** 10.13813/j.cn11-5141/u.2020.0606-en

Keywords: transportation planning; park and ride; connecting traffic; externality; Shanghai

0 Introduction

With the rapid development of rail transit, many megacities and large cities, such as Beijing, Shanghai, Guangzhou and Shenzhen, have planned and built a certain number of park and ride (P&R) facilities around rail transit stations in peripheral areas and outskirts. The purpose is to prevent cars in the peripheral areas and outskirts from entering urban areas so that traffic congestion in downtown areas can be mitigated. Shanghai has conducted a lot of practice in the development of P&R parking lots. The earliest example is the opening of P&R parking lots on Songhong Road and Hongmei Road in 2009. By 2020, the government has opened 19 P&R parking lots with more than 5,000 parking spaces, and more than 20 P&R parking lots with certain scales were formed spontaneously with about 4,000 parking spaces. These P&R parking lots are located in different areas of the city. The actual usage of many P&R parking lots is quite different from the expectation, which leads to great uncertainty and mixed social evaluation.

In the planning of P&R parking lots, the key problem is how to transform P&R into transit oriented development (TOD) to ensure that the planning achieves the expected effect. Researches on foreign cities with relatively developed rail transit systems show that the car usage demand in outskirts around rail transit stations decreases by 44% [1] compared with that in outskirts without rail transit stations. In the development of rail transit system in many China's large cities, planning P&R parking lots becomes a normal planning technique, but its practical effects remain to be evaluated. Therefore, this paper systematically analyzes and evaluates Shanghai's practices on P&R parking lots to summarize experience and provide guidance for subsequent planning and construction, with the ultimate goal to build a multi-layer transit-oriented urban space structure.

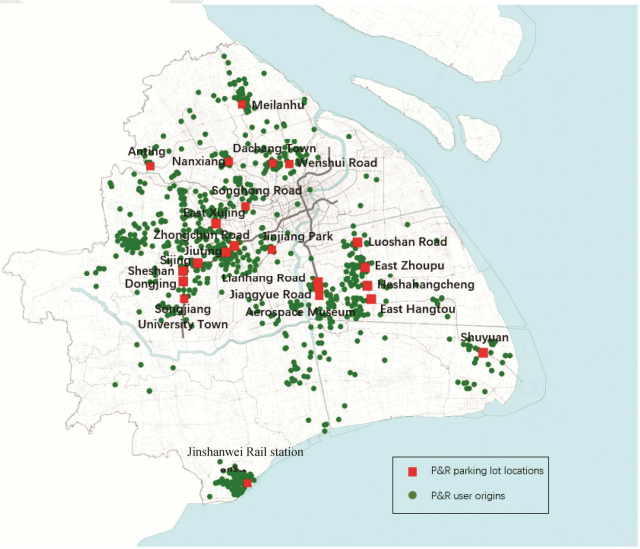

Fig. 1 Distribution of P&R parking lots and users' origins

Received: 2020-04-29
Supported by: National Natural Science Foundation of China (51778431)
First author: LIU Tao (1982–), male, from Jinzhou of Hebei Province, PhD candidate, senior engineer, registered urban planner, registered consulting engineer, is mainly engaged in urban transportation planning and intelligent transportation. E-mail: taoliu82@163.com
Corresponding author: PAN Haixiao (1962–), male, from Huainan of Anhui Province, PhD, professor, PhD supervisor, is mainly engaged in urban land use and transportation planning. E-mail: hxpank@126.com

1 Characteristics of the usage of P&R parking lots

1.1 Source of vehicles and usage of P&R parking lots

The paper investigated 23 P&R parking lots in Shanghai, among which 10 were built with government fund and 13 were formed spontaneously. The parking lots built with government fund are subsidized by the government and their parking charge is below the market price. The locations of these P&R parking lots and origins of users are shown in Fig. 1, which are represented by red squares and green dots respectively.

A total of 1,405 questionnaires were distributed manually to the users of P&R parking lots and 1,315 valid questionnaires were collected. The sampling rate for large parking lots that serve more than 100 vehicles per day is 20%–30%, while it is about 50% for small parking lots.

The usage of the 23 P&R parking lots is summarized in Tab.1. The table shows that the utilization rates of some parking lots are as high as 100%, such as the parking lots at Songhong Road Station, Xujing East Station and Shendu Highway Station. These stations have a high demand for parking lots and parking lots are popular among residents near these stations. On the other hand, the utilization rates of some parking lots are below 35%, such as the parking lots at Gonghexin Road Station, Dachang Town Station and Songjiang University Town Station.

Tab. 1 Usage of P&R parking lots

Metro station	Number of parked vehicles	Capacity	Utilization rate/%	Metro station	Number of parked vehicles	Capacity	Utilization rate/%
Shendu Highway	496	496	100	Meilanhu	200	455	44
Lianhang Road	24	24	100	Dachang Town	90	700	13
Jiangyue Road	30	42	71	Gonghexin Road	100	370	27
Jinshanwei	500	500	100	Jinjiang Park	30	72	42
Songjiang University Town City	100	331	30	Nanxiang	100	180	56
Jiuting	300	300	100	Anting	30	200	15
Dongjing	25	25	100	Shuyuan	120	206	58
Sheshan	100	211	47	Hangtou East	90	159	56
Sijing	25	25	100	Heshahangcheng	50	50	100
Zhongchun Road	60	70	85	Zhoupu East	90	100	90
Songhong Road	292	292	100	Luoshan Road	70	70	100
Xujing East	1 300	1 300	100				

A comprehensive analysis was conducted on these P&R parking lots to analyze their locations in the city, the characteristics of the traffic around them and their locations on rail transit lines. The analysis indicates that the demand for P&R parking lots is high for stations on peripheries of congestion zones, at the end of rail transit lines and along rapid rail transit lines. It also indicates that the demand for P&R parking lot is low for stations in congestion zones and along common speed rail transit lines [11].

1) An example of the P&R parking lot on peripheries of congestion zones is the parking lot at Songhong Road Station. Drivers can drive into the parking lot smoothly and arrive at their destinations fast after transferring to rail transit, which allows them to avoid road congestion in urban areas. This travel route, as the fastest way to travel from the outskirts to the downtown area, can give full play to the speed advantages of cars and rail transit.

2) Examples of the P&R parking lots at the end of rail transit lines include the parking lots at Xujing East Station and Shendu Highway Station. This type of P&R parking lot can effectively address the deficiency in rail transit coverage and meet the transfer demand in the large areas at the end of rail transit lines, which are far away from the downtown area. If the terminal station is in the main commuting area of the city at the same time, the transfer demand will be very obvious.

3) An example of the P&R parking lot along the rapid rail transit line is the parking lot at Jinshanwei Station. Rail transit has a big speed advantage over road traffic, which allows drivers to arrive in the downtown area fast after they park their cars and transfer to rail transit. This kind of P&R parking lot is very attractive and has a large scope of attraction.

4) Examples of the P&R parking lots in congestion zones include the parking lots at Dachang Town Station and Wenshui Road Station. Drivers from the peripheries need to drive into congestion zones when they travel from their origins to the parking lots in congestion zones, which takes a long time. In addition, when they transfer to rail transit, the major part of their trip has been completed and their carriages are usually very crowded. Therefore, the usage of these parking lots leads to trips with low timeliness and comfortableness.

5) Examples of the P&R parking lots along common speed rail transit lines include the parking lots along Lines 9 and 16. They mainly serve the residents within a small distance from the rail transit stations.

1.2 Connecting distance for driving

Connecting distance exerts a major influence on the selection of connection modes. The investigation results show that the proportion of travelers choosing P&R parking lots will rise along with the increase of connecting distance (Fig. 2). An interpolation calculation on data in Fig. 2 indicates that the connecting distances corresponding to the first, second and third quartiles of the P&R proportion are 1.83 km, 3.57 km and 5.71 km, respectively. Cars have a big advantage for trips with a long connecting distance. However, for trips with a short connecting distance, a multimodal connection system can be designed to reduce the investment and space demand of P&R parking lots.

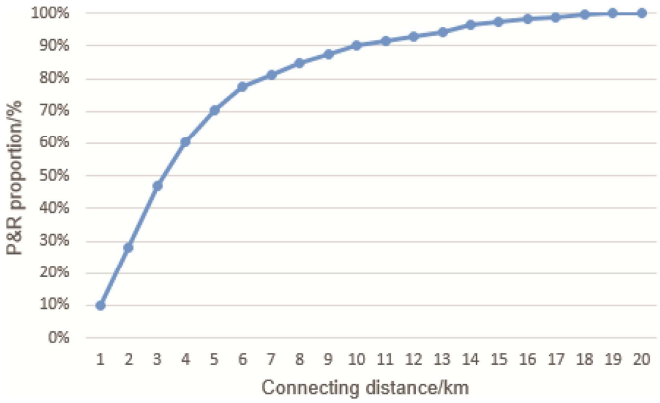

Fig. 2 Proportions of P&R users under different connecting distances

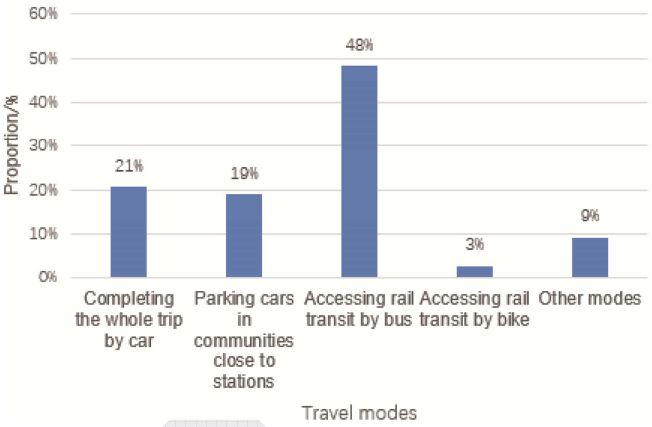

Fig. 3 Connection modes used before the opening of P&R parking lots

The four major connection modes for rail transit are walking, non-motorized vehicles, buses and cars. Within 1.83 km from the rail transit station, walking and non-motorized vehicles are the most effective connection modes and they are also the green travel modes that deserve to be advocated for. Over 1.83 km from the rail transit station, the connecting distance is beyond most people's physical travel limitations in light of the current transportation environment [10], and travelers prefer motorized mode. However, in the areas 1.83 km away from the rail transit station, especially in the outskirts with low population density, there are fewer buses and the departure intervals are long in consideration of operation efficiency [9]. Therefore, buses fail to meet the travel demand in these areas, and car connection becomes an attractive choice.

1.3 Shift of connection modes

How the users of P&R parking lots transfer to the parking lots is a key factor to evaluate the external effects of P&R. This investigation shows that before the opening of P&R parking lots, nearly 50% of travelers adopt bus connection, which accounts for the largest proportion, followed by travelers who complete the whole trip by car (Fig. 3). P&R parking lots attract plenty of travelers who adopted bus connection, but the proportion of such travelers differs greatly for different stations. For example, the proportion of travelers who shift from buses to P&R is 66% for Songhong Road Station, whereas it is only 13% for Sijing Station.

According to the characteristics of traffic mode transfer, P&R stations are divided into three categories. 1) For example, there were 5 bus lines at Songhong Road Station with a departure interval less than 6 min in the morning rush hour. The low rate of CNY 10 per day of P&R parking lot in Songhong Road promotes the transfer of travellers who adopted bus connection to P&R mode. 2) Before the completion of P&R parking lot, there are open parking spaces or vacant land in the surrounding areas. For example, 52% of the P&R users in Sheshan station had previously parked in the surrounding areas or vacant land. After the completion of P&R parking lot, all the cars parked around the station were transferred here. 3) There are no high-frequency bus lines and available parking spaces around the station. For example, the proportion of the transfer of the travelers who complete the whole trip by car in Sijing Station is as high as 47%.

The source of transfer vehicles depends on existing connection facilities, parking rate and bus service level. For stations without high-frequency bus service or other types of parking space, P&R parking lots are particularly important. For stations with high-frequency bus connections, cars will compete with buses and cause a reduction in bus passenger flow. Meanwhile, the emission intensity of pollutants from short-distance connecting cars is high, which is not conducive to sustainable development.

2 Social benefits and externality of the P&R mode

2.1 Social benefits

The domestic and foreign P&R practical experience is summarized, which reveals the main functions of P&R parking lots: 1) easing traffic congestion in downtown areas [2–3] by intercepting cars traveling from outskirts to downtown areas [8]; 2) increasing the attractiveness of rail transit and expanding the attraction scope of rail transit stations [5]; 3) improving the convenience of travel, and increasing an alternative way of travel.

The roles of different types of P & R parking lots at different locations differ greatly [3,6–7]. P & R parking lots on peripheries of congestion zones perform well in intercepting cars traveling from outskirts to downtown areas. For example, more than 40% (about 150 vehicles) of users in the P&R parking lot at Shendu Highway Station used to travel from outskirts to downtown areas. P&R parking lots at the end of rail transit lines can extend the coverage of the station. The average connecting distance for users of the Xujing East Station parking lot is 12.3 km. P&R parking lots along rail transit lines can not only improve the convenience of the

residents around the station, but also expand the attraction scope of these stations. On the other hand, P&R parking lots in congestion zones show little effect on the improvement of traffic conditions.

2.2 Externality

P&R vehicles are mainly shifted from three connection modes. Among these shifts, the shift from car as the travel mode of the whole trip to P&R and the shift from bus connection to P&R cause a change in the traffic structure (Fig. 4). Therefore, from the perspective of time saving, this paper only discusses the impact of these two types of transfer. The impact of parking rate and parking space supply at destinations on P&R mode transfer is beyond the scope of this paper.

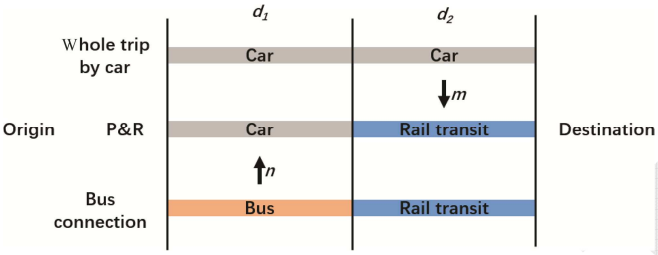

Fig. 4 Change of traffic volume caused by transfer to P&R

In Fig.4, d_1 is the distance from the origin to the P&R parking lot, and d_2 is the distance from the P & R parking lot to the destination. m is the number of users who transfer from by car in the whole trip (assuming they all drive alone), and n is the number of users who transfer from bus connection.

1) Traffic structure

d_1 segment of the road is relatively smooth. For travelers, cars have advantages of speed and flexibility over buses, and the traffic mode of n travelers changes from bus to car. Therefore, the change in traffic structure on the d_1 segment shows negative externalities. Since the d_2 segment is congested and rail transit is much faster than cars, the traffic mode of m travelers changes from car to rail transit. Therefore, the change in traffic structure on the d_2 segment shows positive externalities. On the whole, P&R parking lots attract m travelers who originally would park cars in downtown areas and induce n cars that originally would not travel.

2) Total travel time

Without bus-priority policies, cars travel faster than buses on the d_1 segment and the total travel time is reduced. On the d_2 segment, the travel time is reduced for travelers who shift their travel mode from by cars to by rail transit; as the traffic volume on the road decreases, and the travel time of P&R travelers and road traffic travelers is shortened. Therefore, the total travel time of the system is saved.

3) Road traffic volume

The increase of road traffic volume in d_1 segment is n, the decrease of road traffic volume in d_2 segment is m. The change of total car trips in the road network system is $n - m$. The overall change of road traffic volume depends on the size of n and m. Based on the proportions shown in Fig.3, when n is greater than m, the total road traffic volume increases. Nevertheless, the P&R mode can balance the car traffic volume between the city center and the outskirts.

4) Vehicle kilometers traveled

The increase of vehicle kilometers traveled (VKT) in d_1 segment is $d_1 \times n$, in d_2 segment is $d_2 \times m$. The decrease of VKT in the whole process is $d_2 \times m - d_1 \times n$.

The parking volume of P&R parking lot at Shendu Highway Station is 496, 149 cars (30%) are transferred to P&R mode, and 238 buses (48%) are transferred to P&R mode. The distance from Shendu Highway Station to People's Square in the center of the city is 20 km, the average connecting distance is 8.16 km. Therefore, the VKT is decreased by 1037.92 pcu·km daily.

The parking volume of P&R parking lot at Songhong Road station is 292, 67 cars (23%, completing the whole trip by car) are transferred to P&R mode, 192 buses (66%, bus connection) are transferred to P&R mode. The distance between Songhong Road Station and People's Square of Shanghai is 12 km and the average connecting distance is 5 km. Therefore, the VKT is increased by 156 pcu·km daily.

In summary, whether the P&R mode can reduce VKT depends on the location of the P&R parking lot and the changes in the traffic structure.

5) Ridership of public transportation

The ridership of rail transit increases by m on the d_2 segment, and the ridership of connecting buses decreases by n on the d_1 segment. The overall ridership of the public transportation system, therefore, changes by $m - n$. It is evident that the P&R mode plays a positive role in the increase of the rail transit ridership. Since the ridership of connecting buses drops by n, connecting bus lines can further optimize and adjust transportation capacity after the opening of P&R parking lots.

3 Advice on the planning of P&R parking lots

1) On the basis of clarifying the function of P&R parking lot, the layout is planned by type and location.

The functions of P&R parking lots are related to their locations on rail transit lines. The function of P&R parking lots on peripheries of congestion zones is to intercept cars heading to downtown areas. The function of P&R parking lots at the end of rail transit lines is to address the deficiency in rail transit coverage and to expand rail transit's service range. The function of P&R parking lots along rail transit lines is to provide more connection convenience. P&R parking lots should be planned in the peripheries of urban congestion zones and in line with travel demand management (TDM) policies. Large P&R parking lots can be planned for stations at the end of rail transit lines. Small P&R parking lots can be planned in the form of "pearl chain" along rail transit lines in outskirts. It is not suitable to set up P&R parking lots in downtown areas.

2) An integrated connection system should be built to include the P&R mode and other connection modes such as buses, walking, and non-motorized vehicles.

The connection modes of walking and non-motorized vehicles should be encouraged when the connecting distance is no more than 1.8 km. When the connecting distance is between 1.8 and 5.7 km, the connection modes of non-motorized vehicles, buses and cars can all be considered with the emphasis on non-motorized vehicles and buses, so as to avoid the low charge of P&R parking lot competing for existing bus passenger flow. In the low-density area larger than 5.7 km, especially in the area with poor economic benefit and low service level of bus operation, the connection mode of cars should be considered, and a certain scale of P&R parking lot should be set up in the rail transit station, but the proportion of travelers in this part is small, so the scale of P&R parking lot should be controlled.

3) External effects should be considered in the planning and construction of P&R parking lots.

In the planning and construction of a P&R parking lot, its external effects should be estimated comprehensively based on its location and the situation of the existing connecting transportation system around the station. For the parking lot with good external effect, the scale can be appropriately expanded. For the parking lot with poor external effect, the scale of parking lot should be controlled properly and their usage should be regulated through a series of management measures, such as parking fees, to maximize the comprehensive benefits of P&R parking lots.

4) P&R parking lots should be built jointly with other types of parking lots and managed dynamically, and the change of future functions should be considered.

P&R parking lots mainly serve commuters and they show apparent “tidal” characteristics. On the other hand, commercial parking lots mainly meet the parking needs in the evening and on non-working days, and residential parking lots mainly meet the parking needs at night. At some comprehensive stations, P&R parking lots can be built and used jointly with commercial facilities to improve the overall service efficiency of the parking facilities. The functions and benefits of P&R parking lots should be assessed regularly. When its function changes, for example, the parking lot outside the congestion area becomes the parking lot inside the congestion area, then the property of the parking lot can be transformed into a commercial parking lot or a bus hub parking lot without preferential charges.

5) The building of P&R parking lots should promote the reallocation of urban road space.

The building of P&R parking lots is related to the allocation and reoptimization of urban road space. The construction of large-scale rail transit should be accompanied by the reduction in car traffic capacity along the rail transit corridor. Car space can be converted to space for buses, walking and non-motorized vehicles to improve the urban quality of life.

4 Conclusions

Although P&R facilities have been planned in the construction of the rail transit network in some cities, how to improve the comprehensive benefits of multiple transportation modes to promote sustainable development is still an issue worth considering. Many factors need to be considered in the planning and operation of P&R parking lots. First, the functions and positioning of P&R parking lots should be defined clearly, and P&R parking lots should be planned based on the characteristics of their locations. In the central area of the city, the construction of P&R parking lot should be controlled. The feasibility of functional adjustment of P&R parking lots should also be considered in planning. Second, car connection is only a connection mode of rail transit station. We should consider the coordination and integration with other connection modes. Improving bus service and non-motor vehicle parking facilities can also greatly reduce the demand for P&R parking lot. Finally, before construction, the externality of P&R parking lot should be fully analyzed, and flexible operation and management methods should be adopted to give full play to the comprehensive benefits of P&R parking lot.

References

[1] Cervero R. Vehicle Trip Reduction Impacts of Transit-Oriented Housing [J]. Journal of Public Transportation, 2008, 11 (3): 1–17.

[2] Graham P. Park and Ride: Could It Lead to an Increase in Car Traffic? [J]. Transport Policy,1995, 2 (1): 15–23.

[3] Meek S, Ison S, Enoch M. Role of Bus-Based Park and Ride in the UK: A Temporal and Evaluative Review [J]. Shao Ling, Lyu Yongbo, translated. Urban Transport of China, 2011, 9 (1): 78–94.

[4] Fan Wenbo. Experience and Enlightenment of Oxford City’s Bus-Based Park and Ride [J].Journal of Transportation Engineering and Information, 2013 (1): 44–50.

[5] Luo Limei. The Research of Park and Ride Planning and Design Methods in the Periphery of the Historical City [D]. Nanjing: Southeast University, 2011.

[6] Meek S, Ison S, Enoch M. Stakeholder Perspectives on the Current and Future Roles of UK Bus-Based Park [J]. Journal of Transport Geography, 2009 (17): 468–475.

[7] Jiang Binglei. Several Introspections of Developing P + R Facilities [J]. Traffic & Transportation, 2015 (5): 49–50.

[8] Pan Haixiao, Du Lei. Travel Mode and Intermodality. Shanghai: Tongji University Press, 2003.

[9] Luo Jiangfan, Li Qingyao, Wu Yan, et al. The Access Traffic Research of “Last One Kilometer” of Railway Station [J]. Modern Urban Transit, 2016 (4): 93–98.

[10] Liu Tao. Research on Connecting Transportation Planning of Residential Station in Suburban Rail Transit [J]. Housing Science, 2020, 40 (3): 56–58.

[11] Liu Tao. Research on Planning and Layout of Car Park and Ride Railway Lots [J]. Urbanism and Architecture, 2019, 16 (9): 89–90.

