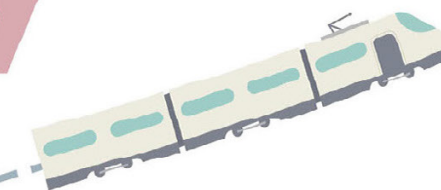
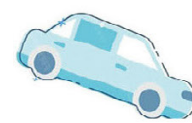
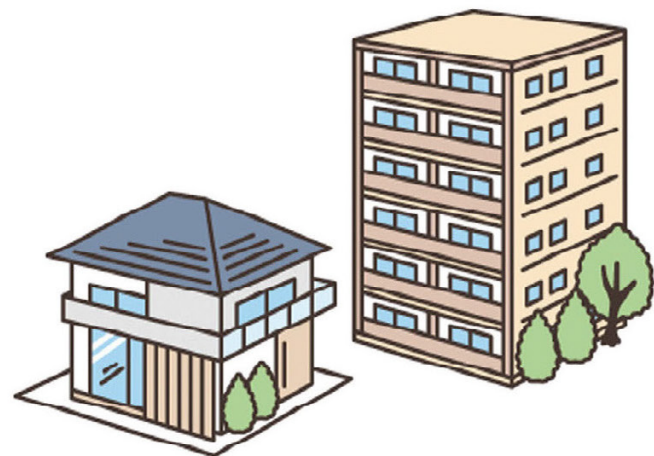


# Park Peacefully Transfer Rapidly



Field Research on Current Utilization, Policy Impact,  
and Strategic Improvements of Park-and-Ride Sys-  
tems in Hangzhou





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Appendix**[Abstract]**

This field research investigates the effectiveness of Park and Ride (P+R) facilities integrated with Hangzhou Metro, focusing on their capacity to reduce carbon emissions and urban congestion. Utilizing a mixed-methods approach, the research combines quantitative data analysis, field observations, and qualitative interviews across five strategically selected metro stations. The findings highlight that P+R facilities substantially decrease the need for urban car usage by shifting commuter behavior from private vehicles to public transportation, consequently reducing both carbon emissions and traffic congestion.

Despite these benefits, the study also uncovers several operational challenges such as insufficient parking spaces, underutilization of certain P+R lots, and technical glitches in payment systems. These issues underscore a misalignment between facility capacity and commuter needs, particularly during peak hours, which impacts overall effectiveness.

Recommendations for future policy include optimizing spatial distribution, enhancing fee structures, and improving real-time data integration to better meet commuter demands and increase usage rates. By addressing these points, Hangzhou can enhance the functionality of its P+R systems, making them more attractive and efficient, thereby supporting broader environmental and urban mobility goals. The research concludes that while P+R systems are pivotal in promoting sustainable urban transit, their potential is maximized only when aligned meticulously with user needs and urban infrastructure planning.

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**[Key words]**

#Sustainability

#Park and Ride

#Questionnaire

#Transportation policy

#Urban congestion

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## Chapter 1. Interduction

## 1.1 Background

Urban car use exacerbates carbon emissions; thus, rail transit emerges as a feasible mitigation strategy, prompting a robust advocacy for park and ride(P+R) facilities.

Sustainable development is seen as key to addressing global issues, with the transportation sector both vital for socio-economic infrastructure and a major emitter, contributing 10% to China's total carbon emissions by 2023. Urban rail transit, exemplified by Hangzhou's efforts in smart transportation, plays a crucial role in reducing carbon emissions and improving urban sustainability through its efficiency and low emissions.

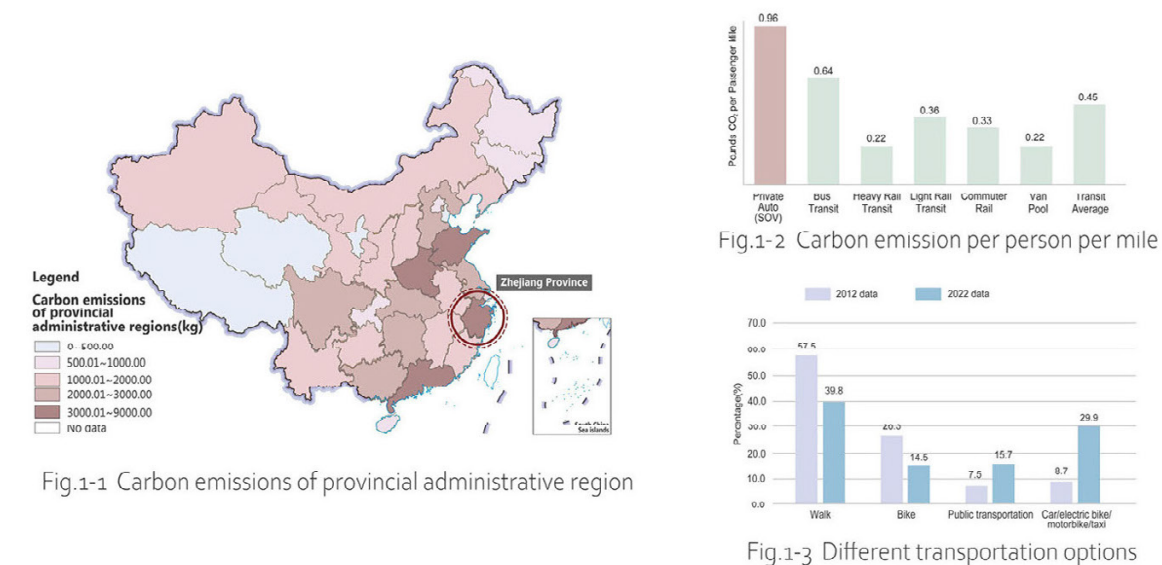
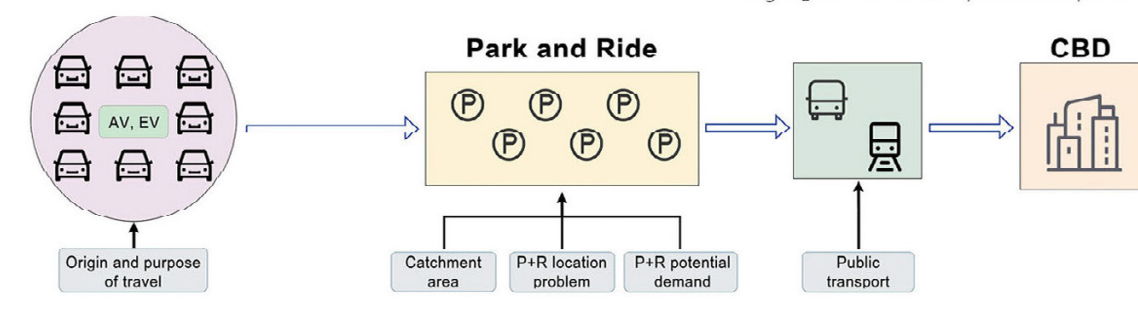


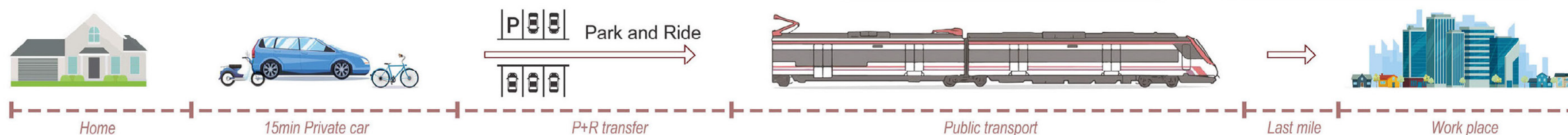
Fig.1-1 Carbon emissions of provincial administrative region

Fig.1-2 Carbon emission per person per mile

Fig.1-3 Different transportation options



In response to the growing demands for rail transit and the expanding service areas of railway stations, Park and Ride (P+R) emerges as a potential solution. P+R involves establishing transit facilities on the periphery of urban areas near rail stations, offering low-cost parking for private vehicles. Supported by favorable public transit fare policies, this strategy aims to encourage commuters to switch to public transport for entering central urban areas.



Hangzhou has actively promoted peripheral Park and Ride (P+R) facilities near transit hubs to encourage public transport usage, reduce private vehicle traffic, and alleviate urban congestion. This approach is vital for urban traffic management and broader environmental objectives. Consequently, our research examines the policy impact of Hangzhou's P+R facilities on transit efficacy and carbon emissions reduction.

## 1.2 Research object

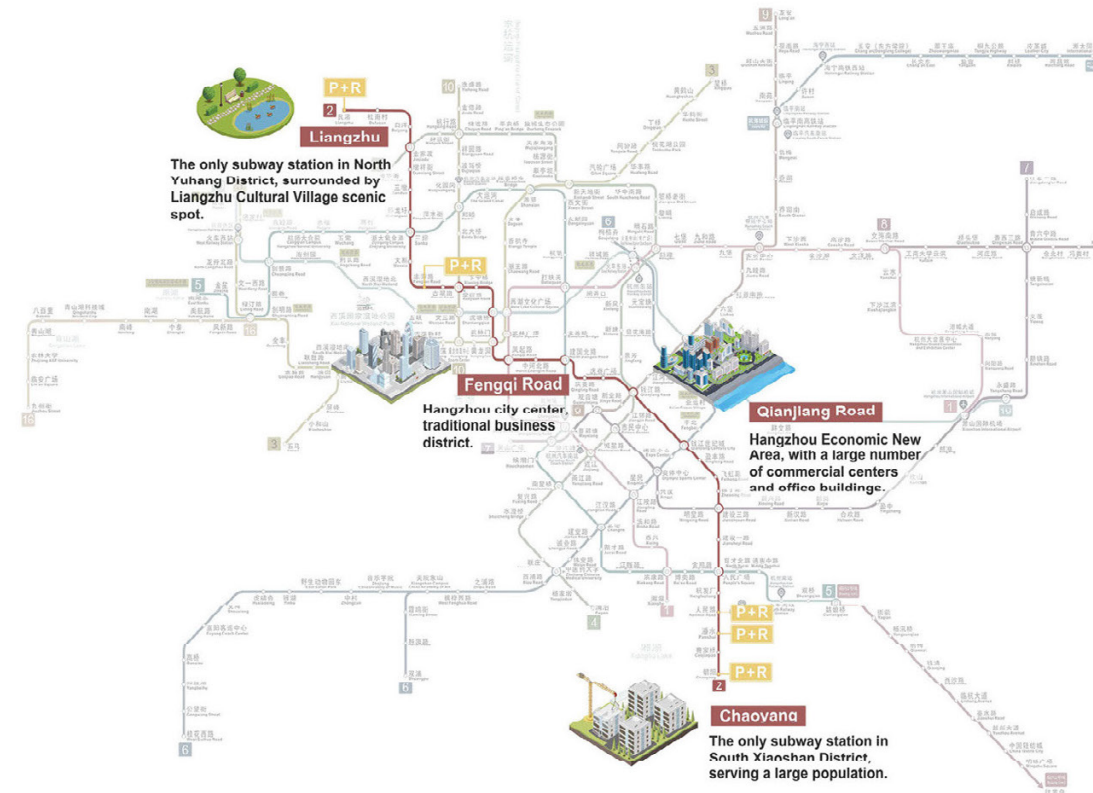


Fig.4 Introduction to Hangzhou Metro Line 2

## WHAT?

Hangzhou Metro Line 2, an integral part of the city's transit system and one of its busiest with a daily ridership of around 600,000, spans multiple urban zones including Liangzhu, the western residential districts, the eastern new city, and Qianjiang New City. This diversity provides an ideal setting for a comprehensive analysis of P+R systems.

## WHY?

Five stations have been selected for inclusion in the dataset for this study. Key stations with P+R lots include Fengtan Road Station, Renmin Road Station, Panshui Station, and Chaoyang Station. Despite not officially having a P+R facility, Liangzhu Station demonstrates P+R characteristics like pricing and user demographics, is also included in this analysis.

## 1.3 Research target

The objective of this research is to address the following questions:



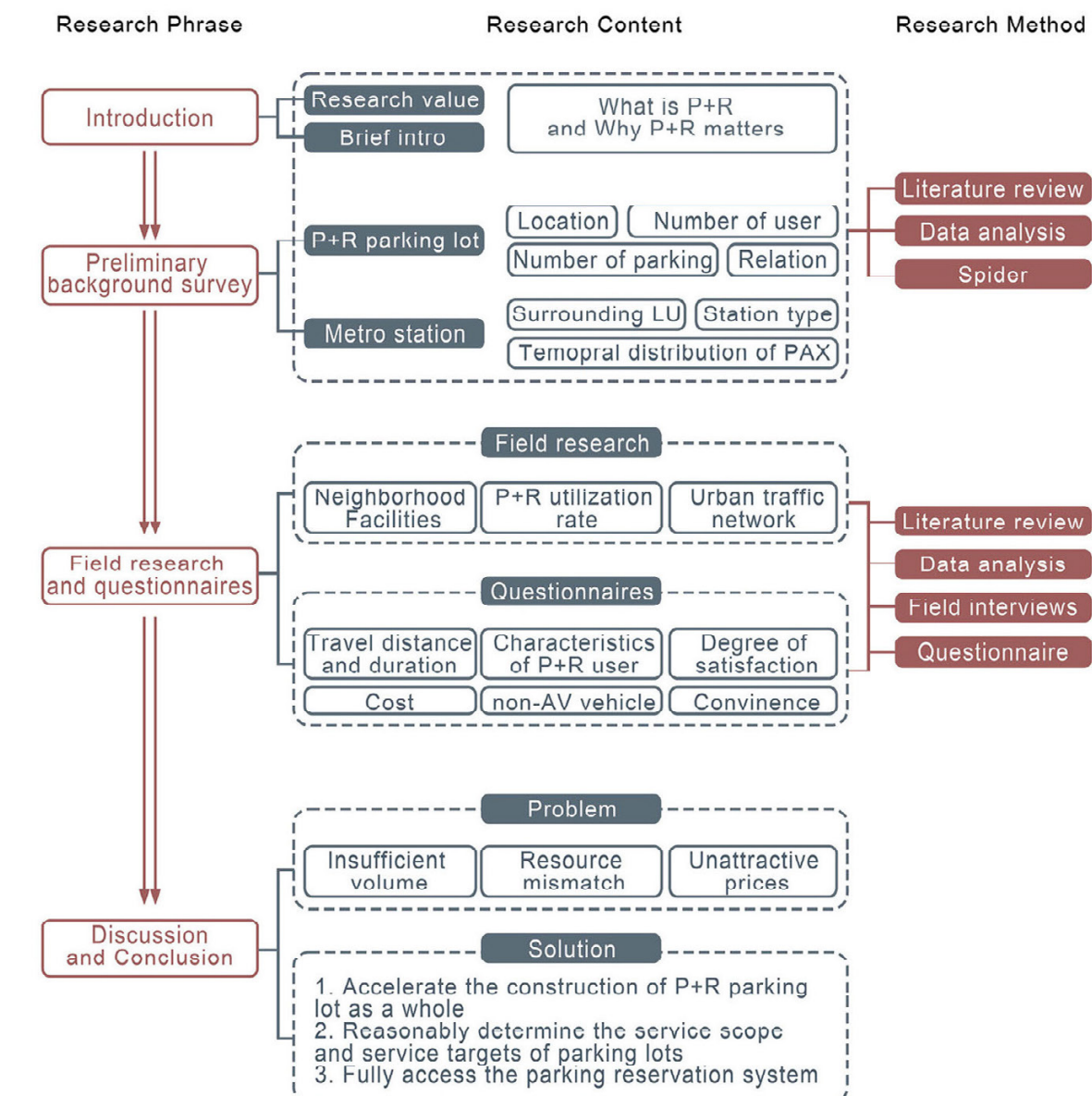
What are the effects of the implementation of the Hangzhou Park and Ride (P+R) system?



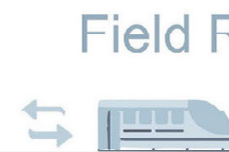
How can the existing P+R system be optimized in terms of spatial distribution, scale selection, and policy formulation?



## 1.4 Research Flow







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## Chapter 2 Current policy and effect review

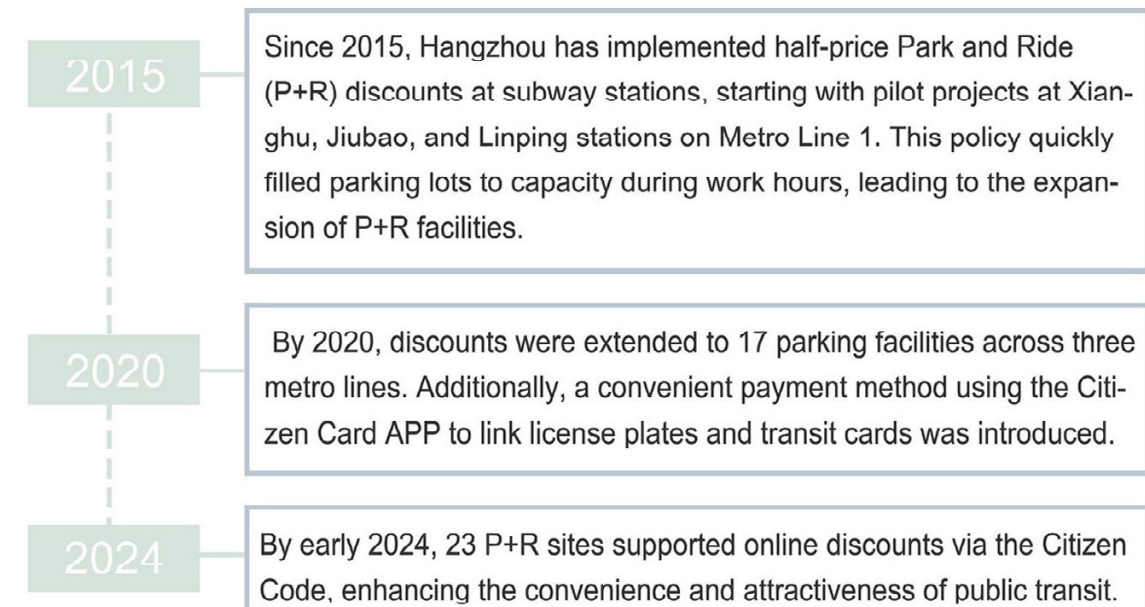
## Chapter 3 P+R use intention and influencing factors

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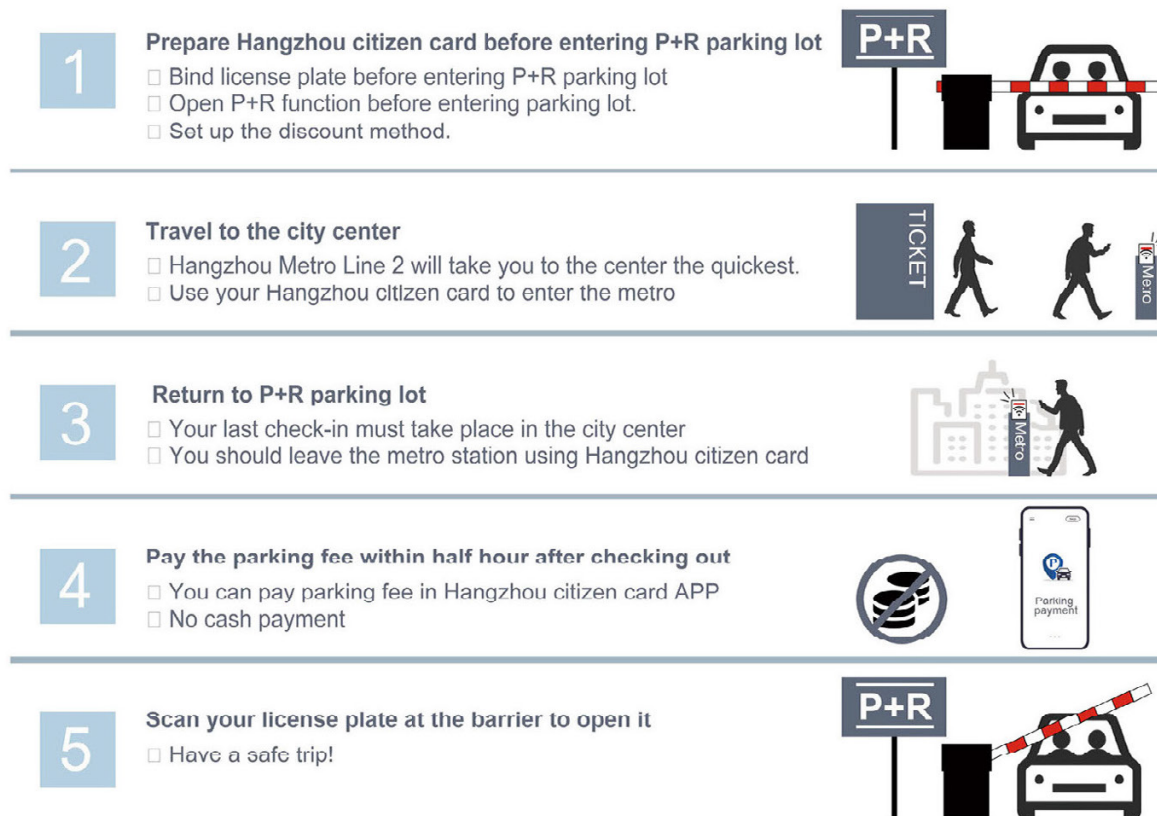
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## Chapter 2. Current Policy and Effect Review

### 2.1 History of P+R policy in Hangzhou



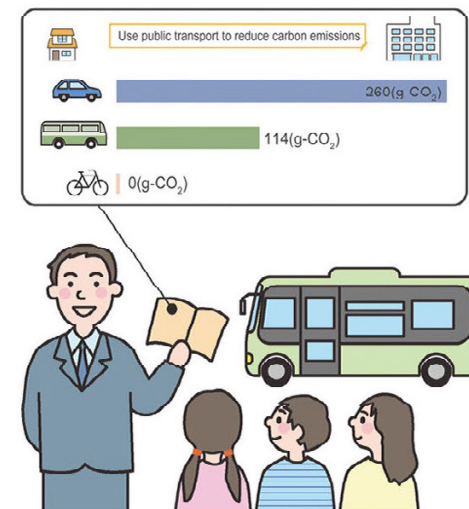
### 2.2 Implementation mechanisms



### 2.3 Socioeconomic implications of P+R systems

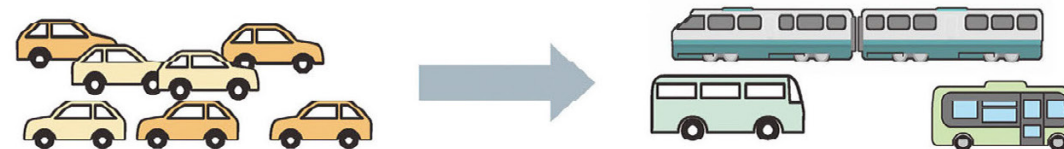
#### Reduction of carbon emissions

- By encouraging suburban residents to utilize the Park and Ride (P+R) policy, which shifts some traffic to the subway system, the frequency of solo driving into city centers is reduced, directly decreasing the total vehicle miles traveled.
- Reduced automobile usage implies a decline in fuel consumption, thereby significantly reducing carbon emissions, aiding in air quality improvement, and combating climate change.



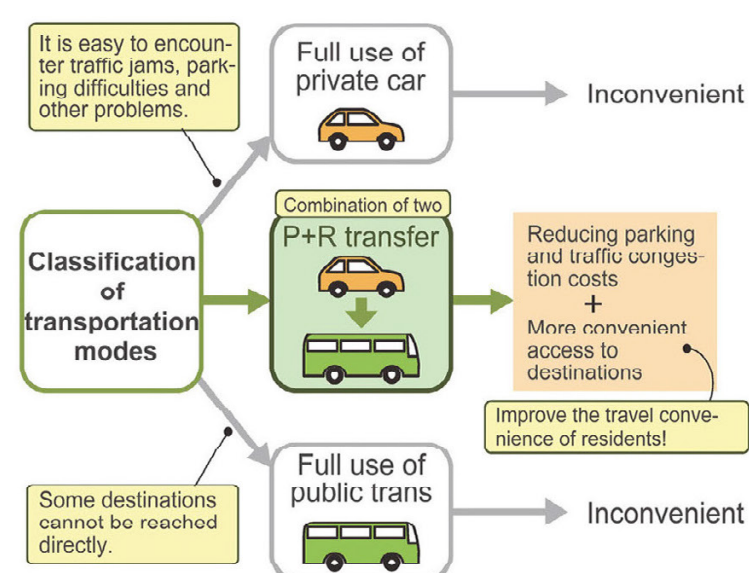
#### Reduction of congestion

- The P+R policy effectively alleviates urban center congestion by reducing the number of vehicles entering city centers.
- Lowering congestion not only reduces commuting time but also decreases additional carbon emissions and air pollution caused by traffic congestion.



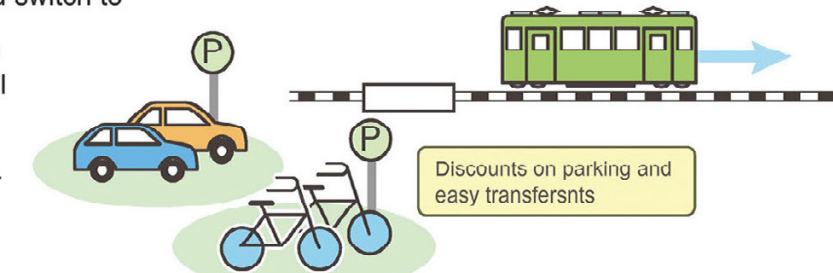
#### Facilitating residents

- For residents living on the urban periphery or in suburban areas, P+R offers a cost-effective option, enabling rapid transit to city centers.
- By reducing the cost of parking at subway stations, P+R policy enhances its attractiveness, encouraging more residents to forego driving the entire commute and instead utilize public transportation.



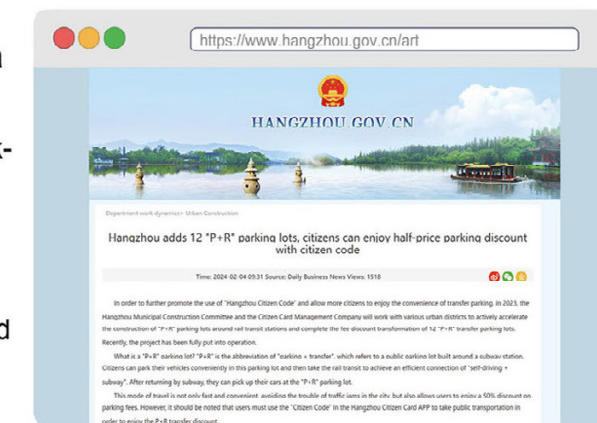
#### Promoting public transportation utilization

- The P+R policy not only alleviates urban traffic pressure but also increases passenger flow to subways and other public transport modes.
- By offering parking discounts, the policy encourages more vehicle owners to park at peripheral locations and switch to public transportation, enhancing the overall usage and efficiency of the public transportation system.

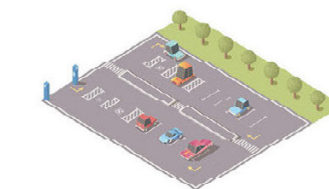


### 2.4 Policy effect review

As of February 2024, Hangzhou has built a total of 27 P+R parking lots covering 8 metro lines, providing more than 5,000 parking spaces, of which 23 parking lots support online settlement discounts through the "Citizen Code". Some of the parking lots provide barrier-free parking spaces and electric bicycle exchange cabinets.



**27**  
parking lot  
supports P+R



**5000+**  
parking space  
supports P+R



**ALL**  
parking lots are  
equipped with accessi-  
ble parking spaces



**6+**  
parking lots are  
equipped with  
charging post

Negative information mainly focuses on the shortage of parking spaces and technical problems of parking facilities. First, parking spaces in popular parking lots, especially in the downtown area, are very tight, and it is often difficult to find a parking space during peak hours, resulting in many people being late for work or having to search for a parking space from a distance. In addition, the technical facilities of some parking lots are not up-to-date in time, with problems such as poor recognition and the inability to use the latest citizen cards.



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Q: How was your experience with the P+R parking lot?

A: Very satisfied, but sometimes there are not enough parking spaces.



Q: Do you think there are any problems with the current P+R parking?

A: Some car owners use the P+R parking lot without transferring to the subway.



Q: Do you have any suggestions for P+R parking?

A: I would recommend parking lots be functionally differentiated and would like to see P+R parking in both downtown and suburban areas.



## BRIEF SUMMARY



Hangzhou's P+R parking system has achieved progress by enhancing infrastructure, including the addition of accessible facilities and change cabinets.

Nevertheless, feedback from citizens and netizens highlights a critical **shortage of parking spaces**, particularly in the city center and popular areas during peak times.

Moreover, **technical issues** and **suboptimal space allocation** continue to impair user experience. Future strategies should focus not only on expanding parking facilities but also on addressing technological impediments and optimizing parking space utilization to better satisfy public demand.

## 2.5 Current future planning

Hangzhou is actively promoting the development of P+R parking lots to facilitate the efficient travel mode of "self-driving + metro". **Future planning focuses on expanding the coverage of such facilities.**

According to the current government work outlook, by 2030, Hangzhou will have 33 P+R parking lots. In addition to the existing parking lots, Hangzhou plans to further build more P+R parking lots and improve the underground connecting channels between the parking lots and metro stations to achieve seamless connectivity.

## Chapter 3. P+R preference and influencing factors: Research, questionnaire and model building

## 3.1 P+R usage characteristics and classification

Through a field survey of five P+R parking lots on Hangzhou Metro Line 2, we obtained the size of the parking spaces at each station, the number of vehicles using P+R for parking, and calculated the utilization rate of P+R.

Tab.3-1 Basic information of the target station

| Station name     | Organization form | Scale | Station Type     | Number of P+R cars | Ratio of passenger using P+R |
|------------------|-------------------|-------|------------------|--------------------|------------------------------|
| Fengtan Road Sta | Inside station    | 885   | Intermediate Sta | 88.5               | 1.12%                        |
| Renmin Road Sta  | Outside station   | 44    | Intermediate Sta | 22                 | 0.27%                        |
| Panshui Sta      | Outside station   | 80    | Intermediate Sta | 40                 | 0.68%                        |
| Liangzhu Sta     | Outside station   | 228   | Terminal Sta     | 114                | 1.38%                        |
| Chaoyang Sta     | Outside station   | 496   | Terminal Sta     | 496                | 6.46%                        |

According to the survey, **these five stations were classified into three categories**: Fengtan Road Station, which is located in the city center and has both P+R and traditional parking functions; Chaoyang Station, which is located in the outskirts of the city and basically serves only P+R functions; and Renmin Road Station, Panshui Station, and Liangzhu Station, which are located in the urban area and exhibit non-motorized P+R and motorized traditional parking functions.

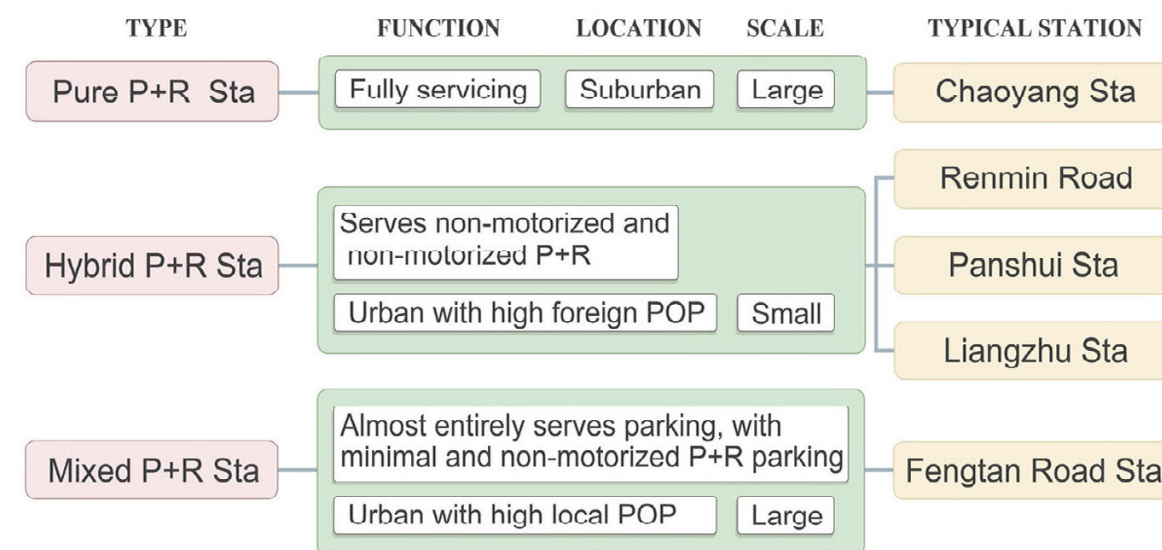


Fig 3-2 General review of three kinds of P+R station

$$\text{Transfer rate} = \frac{N \times p_c \times p_p}{TP} \times 100\%$$

Where, N represents the total number of parking spaces,  $p_c$  represents the proportion of vehicles using P+R for parking,  $p_p$  represents the number of people in each vehicle, and TP represents the average daily number of people using the whole site.

## 3.2 Pure P+R Sites

P+R facility at Chaoyang Station, strategically situated adjacent to Exit A of Subway Line 2, encompasses 496 parking spaces. A pedestrian can conveniently reach the subway turnstiles from the parking exit in approximately 4 minutes.

Tab.3-3 Detailed information of the pure station

| Station name | No. of people served | Density of people served(person/ km <sup>2</sup> ) | Average daily users | Percentage of users at peak times | Transfer rate |
|--------------|----------------------|----------------------------------------------------|---------------------|-----------------------------------|---------------|
| Chaoyang Sta | 103221               | 1748                                               | 23034               | 0.4268                            | 0.0646        |

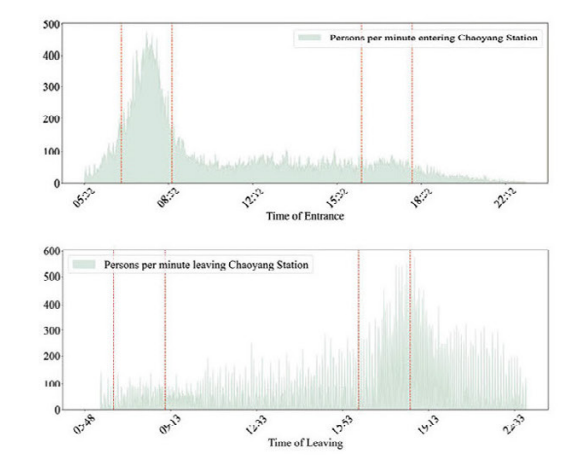
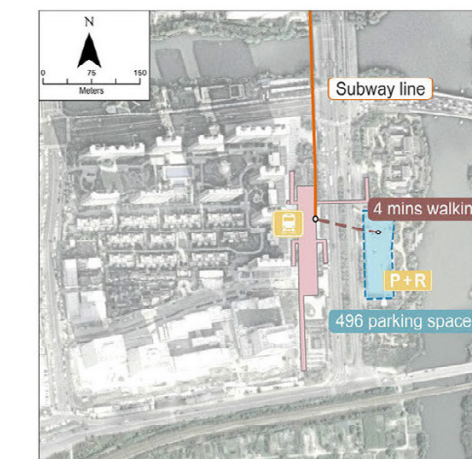


Fig.3-4 Surroundings of Pure P+R Station (a) Relationship between the P+R parking lot and Chaoyang Station, (b) Distribution of the number of people entering the station, (c) Distribution of the number of people exiting the station

## OPERATIONAL DYNAMICS AND CAPACITY UTILIZATION

During typical weekdays, the parking saturation point is reached around 8:15 AM, occasionally necessitating the use of emergency lanes for additional parking. This saturation persists until approximately 4:30 PM, thereafter gradually diminishing as the evening exodus unfolds. By 7:00 PM, most vehicles have vacated the premises.

## PARKING SPACE ALLOCATION AND COST ANALYSIS

Out of the total 496 parking slots at Chaoyang Station, 200 are designated as monthly spaces. However, these monthly spaces are not exclusive and are available on a first-come, first-serve basis. Calculating based on an 8-hour workday and a 5-day work week, the daily rate for the P+R facility is set at 15 RMB, cumulating to a monthly cost of 300 RMB. Conversely, the comprehensive monthly rate is priced at 270 RMB, offering a more cost-effective solution for regular commuters in comparison to the daily P+R rates.





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### 3.3 Hybrid P+R Sites

Hybrid station includes three stations: Renmin Road Station, Panshui Station, Liangzhu Station. We investigated the commonalities of these stations and tried to find the current defects.

Tab.3-5 Detailed information of the hybrid station

| Station name    | No. of people served | Density of people served(person/ km <sup>2</sup> ) | Average daily users | Percentage of users at peak times | Transfer rate |
|-----------------|----------------------|----------------------------------------------------|---------------------|-----------------------------------|---------------|
| Renmin Road Sta | 74300                | 17524                                              | 24365               | 0.3325                            | 0.0027        |
| Panshui Sta     | 67769                | 10723                                              | 17770               | 0.4024                            | 0.0068        |
| Liangzhu Sta    | 56868                | 2541                                               | 24849               | 0.372                             | 0.0138        |

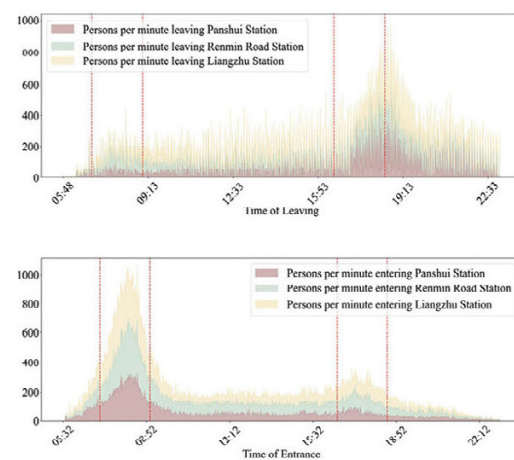
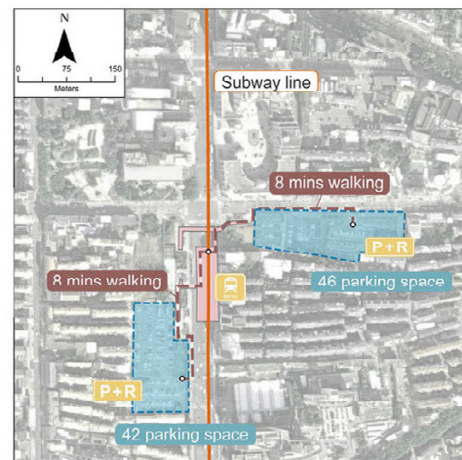
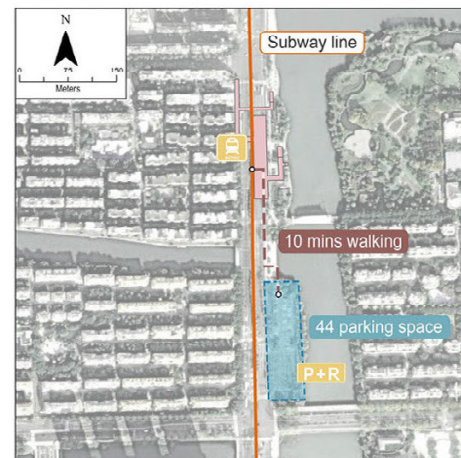
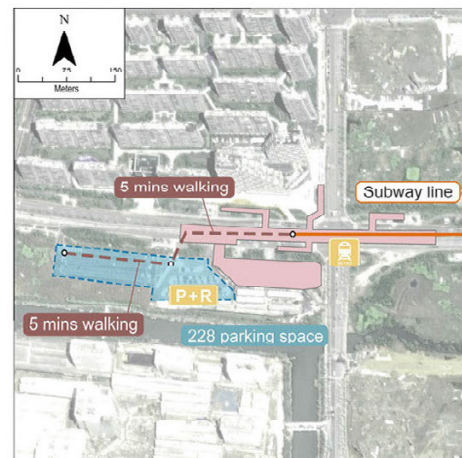


Fig.3-6 Surroundings of Hybrid P+R Station (a) Relationship between the P+R parking lot and Liangzhu Station, (b) Relationship between the P+R parking lot and Panshui Station, (c) Relationship between the P+R parking lot and Renmin Road Station, (d) Distribution of the number of people entering the station, (e) Distribution of the number of people exiting the station

#### FACILITY UTILIZATION AND COMMUTER BEHAVIOR

At the remote Liangzhu Station, 228 parking spaces lie underused at only 70% capacity, making it the least frequented parking spot among Line 2, despite its ample provision. The station, unstaffed and predominantly serving local professionals, contrasts with the always-full non-motorized vehicle areas, revealing a local preference for more accessible and economical transit options.

#### COMMON CHARACTERISTICS ACROSS STATIONS

Both Liangzhu, Panshui, and Renmin Road Stations display unique utilization patterns of their P+R facilities. These stations **lack explicit P+R transfer signage** and **offer limited incentives** for their intended use. Typical parking fees are set without P+R discounts, and no monthly passes are provided.

#### CHALLENGES AND OBSERVATIONS

Renmin Road Station buzzes with activity during peak hours, filled to capacity as vehicles dash in for short-term errands or school runs, diminishing the potential of its P+R facility. A similar scenario unfolds at Panshui Station, where over half of its 80 parking spaces cater to brief visits, not aligning with the intended P+R functions. **The absence of amenities such as eateries or convenience stores only exacerbates the underutilization**, depriving these spots of their full potential as commuter hubs. Meanwhile, at Liangzhu Station, a stark contrast is evident; while **spaces for non-motorized vehicles fill up each morning**, motorized spots languish unused, signaling a disconnect in meeting the preferences of eco-friendly commuters.

### 3.4 Mixed P+R Sites

The Lianhuagang River Underground Parking Garage, positioned near Exit C of the Fengtan Road Station on Line 2, offers a substantial capacity of 885 parking spaces and is directly connected to the station via an underground passage. It's the first and largest development in Hangzhou to utilize the subterranean space beneath park greenery for public parking.

Tab.3-7 Detailed information of the mixed station

| Station name     | No. of people served | Density of people served(person/ km <sup>2</sup> ) | Average daily users | Percentage of users at peak times | Transfer rate |
|------------------|----------------------|----------------------------------------------------|---------------------|-----------------------------------|---------------|
| Fengtan Road Sta | 39757                | 25004                                              | 23783               | 0.3816                            | 0.0112        |

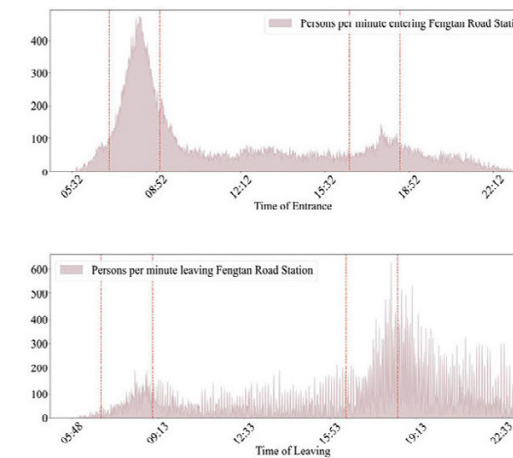
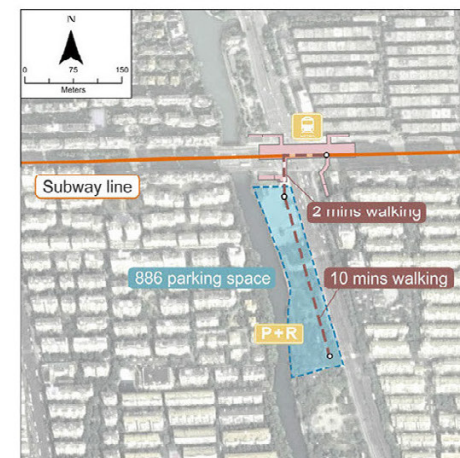


Fig.3-8 Surroundings of Mixed P+R Station (a) Relationship between the P+R parking lot and Fengtan Road Station, (b) Distribution of the number of people entering the station, (c) Distribution of the number of people exiting the station

#### COMPARISON WITH YILE RIVER UNDERGROUND PUBLIC PARKING

In contrast, the Yile River Underground Public Parking, located near Exit A of the same subway station, contains 100 parking spaces and requires exiting the station for transfer, which is less convenient. Both parking facilities offer monthly parking at a rate of 350 RMB/month, with a daily P+R rate of 15 RMB. Under this pricing structure, P+R becomes more cost-effective for commuters who use the service no more than six times per week; otherwise, the monthly parking option is more advantageous.

#### PARKING UTILIZATION AND COMMUNITY IMPACT

A weekday survey at 2:00 PM showed the Lianhuagang River parking facility nearly full, primarily used by locals from nearby aging neighborhoods lacking sufficient parking. With a monthly fee of 350 RMB—more than double the local rate of 150 RMB—residents resort to using this costly option only when necessary. The area, mainly consisting of rental properties occupied by migrant workers since the 1990s, sees these residents often skipping non-motorized transit options in favor of driving directly to their destinations, resulting in lower P+R facility usage.

### 3.5 Questionnaire design ideas

Hangzhou P+R parking utilization and use experience evaluation.

#### Questionnaire theme

#### Targets

The expected targets are users of Chaoyang Station P+R parking lot.

Questionnaire were issued in the connecting channel between P+R parking lot and Chaoyang station.

#### Issuing place

#### Questionnaire structure

The respondents' basic information, the way of using the P+R parking lot and the experience of using.

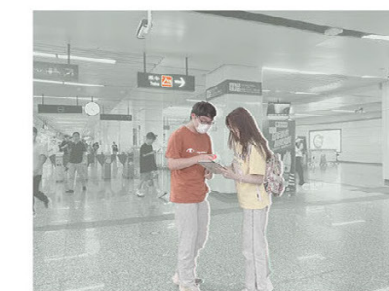


Fig.3-9 Questionnaire survey photo

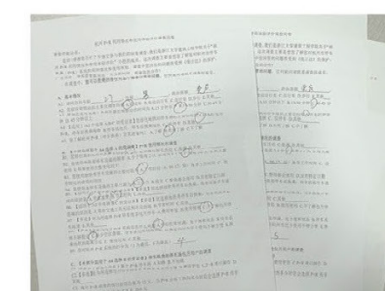
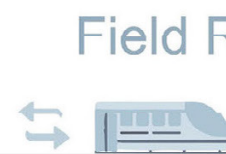


Fig.3-10 Partial questionnaire photo







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## 3.6 Questionnaire statistics and analysis

In the course of the study conducted at the P+R facility adjacent to Chaoyang Station, a total of 34 questionnaires were distributed within the station building. Of these, 33 were returned and deemed valid, yielding a response rate of 97%.

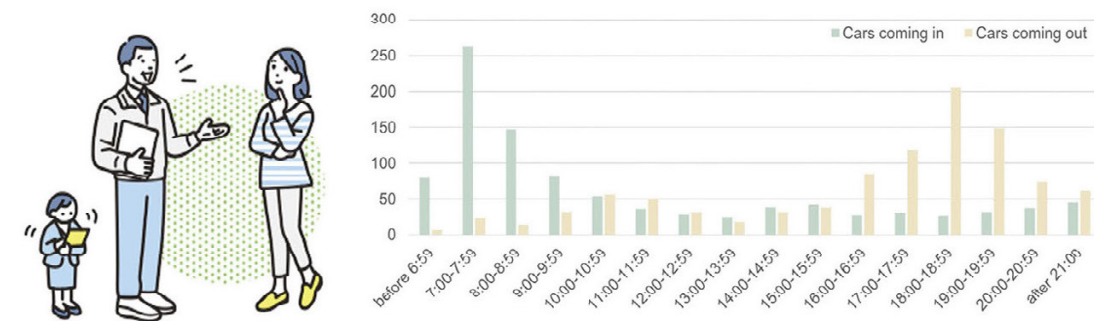


Fig.3-11 Vehicles entering and exiting parking lot hourly



It is noteworthy that minor vehicular activities were also recorded at the facility before 9:00 AM and after 9:00 PM, suggesting that some vehicles utilized the parking area for overnight or short-term parking purposes. These findings highlight the multifaceted role of the Chaoyang Station P+R facility in catering to diverse parking needs.



During typical working hours on weekdays, the facility witnessed a moderate flow of vehicle movements, indicating that the station serves secondary functions beyond just commuting. Notably, the facility was observed to operate at full capacity, occasionally resulting in vehicles entering the parking area only to leave upon finding no available spaces.



Concurrently, the research team meticulously recorded the hourly vehicular ingress and egress at the Chaoyang Station P+R facility. Analysis of the data revealed that vehicular entries peaked before 10:00 AM, particularly during the hours of 7:00 AM to 9:00 AM, before experiencing a significant decline. Conversely, vehicle exits predominantly occurred between 5:00 PM and 7:00 PM. This pattern aligns with typical commuting behaviors, suggesting extensive use of the P+R facility for commuting purposes.

## 3.6.1 Characteristics of respondents

The gender distribution among the respondents was 52:48, closely mirroring the gender ratio (109) of the population in Hangzhou, suggesting that the sampling was reasonably representative. The predominant age group among participants was 26-33 years, accounting for over 50% of the respondents, with an average age of 31 years. In terms of political affiliation, 24% of the respondents were members of the CCP, while 64% were identified as masses. When asked about their mode of transportation to the subway station, 64% of respondents reported driving, whereas 21% utilized non-motorized vehicles.

Overall, 45% of the respondents required less than 15 minutes to reach the subway station, while another 45% needed 15 to 30 minutes. Regarding parking preferences, 40% of the respondents utilized the P+R model, and 49% opted for monthly parking arrangements.

This survey highlights the transportation habits and preferences of commuters in Hangzhou, with a significant portion utilizing the P+R system, reflecting its efficacy and relevance in urban transport dynamics.

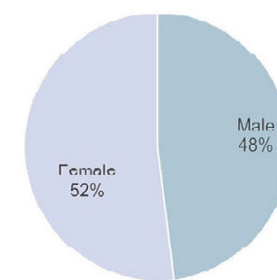


Fig.3-12 Ratio of gender

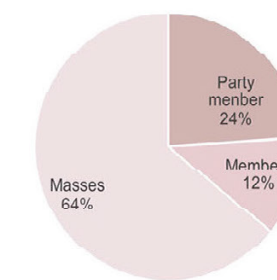


Fig.3-13 Political affiliation of respondents

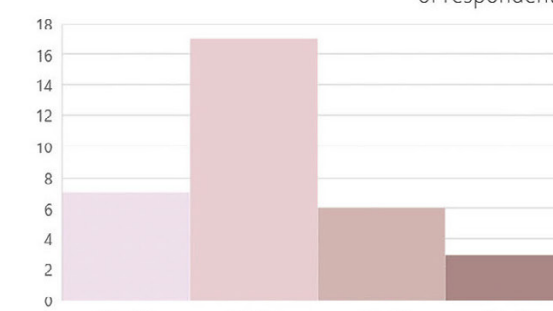


Fig.3-14 Age distribution

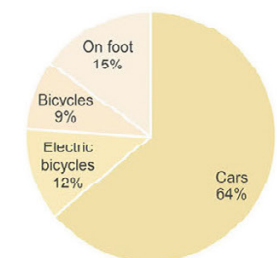


Fig.3-15 Respondents' mode of transportation

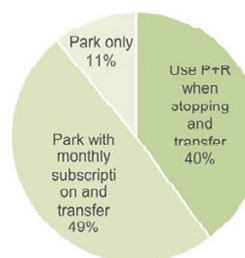


Fig.3-16 Method respondents use the parking lot

**Efficient commute via P+R:** For users utilizing P+R facility followed by a subway transfer, over 80% report reaching the subway station in less than 30 minutes. Considering that the average weekday commute time is approximately 34.7 minutes, this suggests that when driving accounts for more than half of the commute time, commuters prefer driving directly to their destinations over using the P+R facility.

**Usage patterns of P+R users:** Approximately two-thirds of P+R users utilize the parking spaces on weekdays during work hours, while 25% use the P+R facilities on weekends. Over the weekend, the utilization of P+R facilities shifts predominantly towards activities such as shopping, entertainment, and short trips.



**Motivations for choosing P+R:** Over two-thirds of respondents, when asked why they choose P+R over driving directly into the city, cited saving on fuel costs as the primary reason. Additionally, about half of the respondents believe that time savings also significantly influence their decision to use P+R facilities.

**Perceived pros and cons of P+R:** The advantages of P+R are described as convenience of use (50%) and low cost (25%). However, the shortcomings are highlighted as often full parking spaces (83%), an unstable payment system (29%), lack of real-time parking space availability information (13%), and excessive transit distances for transfers (17%).

## 3.6.3 Survey of monthly parking users

This section delves into the preferences and behaviors, comparing monthly parking subscribers to P+R users. The insights gathered reveal significant trends in commuter decisions based on cost and convenience.

**Dominance of monthly parking among commuters:**

The data indicates that almost all users opting for monthly parking are commuters, with a higher proportion compared to P+R users. Remarkably, nearly 90% of these commuters reach the subway within 30 minutes, highlighting the efficiency and convenience of monthly parking for rapid transit access.

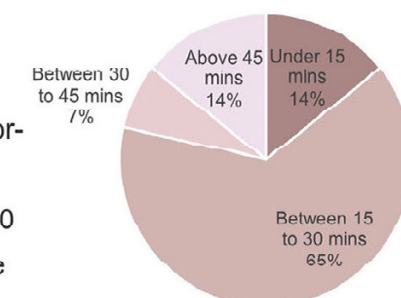


Fig.3-21 Commuting time for monthly parking users

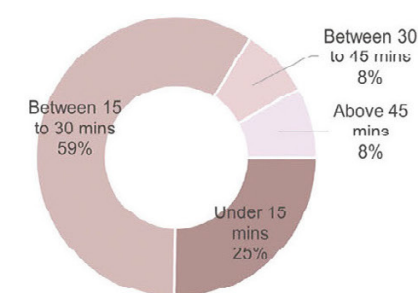


Fig.3-17 Travel time from home to station

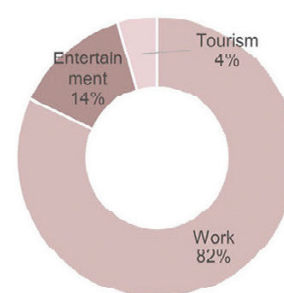


Fig.3-18 Purpose of using P+R parking lot

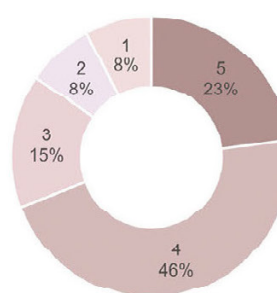


Fig.3-19 Satisfaction rating for P+R parking lot



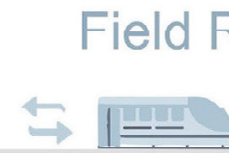
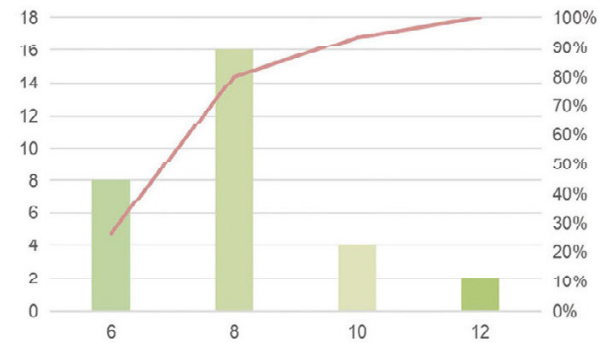
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Fig.3-22 Marginal price for monthly subscribers to choose P+R

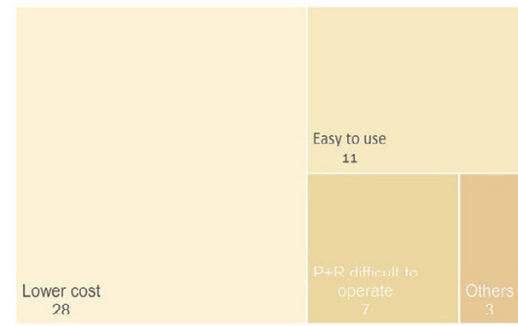


Fig.3-23 Reasons for choosing monthly parking

**Cost-Effectiveness Drives Monthly Parking Preference:** A substantial 86% of users prefer monthly parking over P+R primarily due to its **lower cost**. More than 70% of respondents would switch to P+R if the **daily cap price were reduced to 8 yuan**, suggesting price sensitivity in parking choices. Additionally, 28% of users cite the operational difficulties associated with P+R as a significant reason for their preference for monthly parking.

## 3.6.4 Survey of non-motorized users

This segment of the report explores the commuting patterns and preferences of non-motorized vehicle users, particularly in relation to their **proximity to subway stations** and their reasons for choosing specific modes of transit.

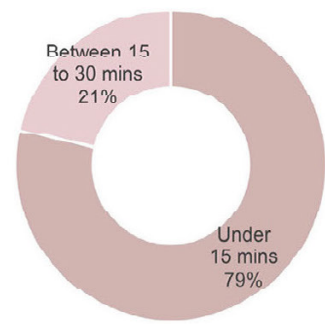


Fig.3-24 Time to reach station

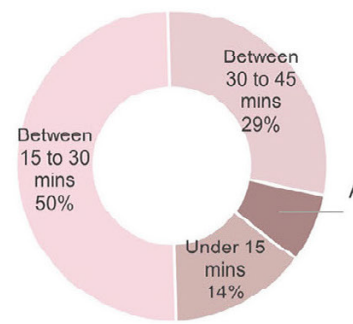


Fig.3-25 Time for subway travel

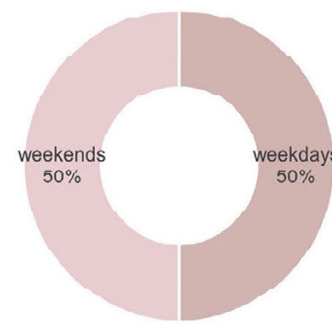


Fig.3-26 Days of the week to use the parking lot

**Reduced transit times for non-motorized vehicle users:** A significant 79% of non-motorized vehicle users report that their travel time to the subway station is less than 15 minutes. This statistic strongly indicates that **most of these commuters reside close to subway stations**, highlighting the convenience and efficiency of using non-motorized vehicles for commuting.

**Commuting habits among non-motorized vehicle users:** The proportion of commuters among non-motorized vehicle users is notably lower compared to other user groups. **Half of the respondents use the parking facilities during weekday work hours**, while the remaining users opt for this mode due to the excessive distance to their destinations, subsequently choosing to transfer to the subway to save time.



## 3.6.5 Construction of P+R willingness-to-use model

Based on the results of the questionnaire survey, we constructed the relationship between **willingness to use P+R** (Willingness to use) and **various basic indicators**, including gender, age, time to station, frequency of metro use (Frequency of metro), whether it is for weekdays (Weekdays or not), Work time or not, Number of P+R, Stores or not, Malls or not, Breakfast or not, and Time of commuting to the subway (Time of commuting).

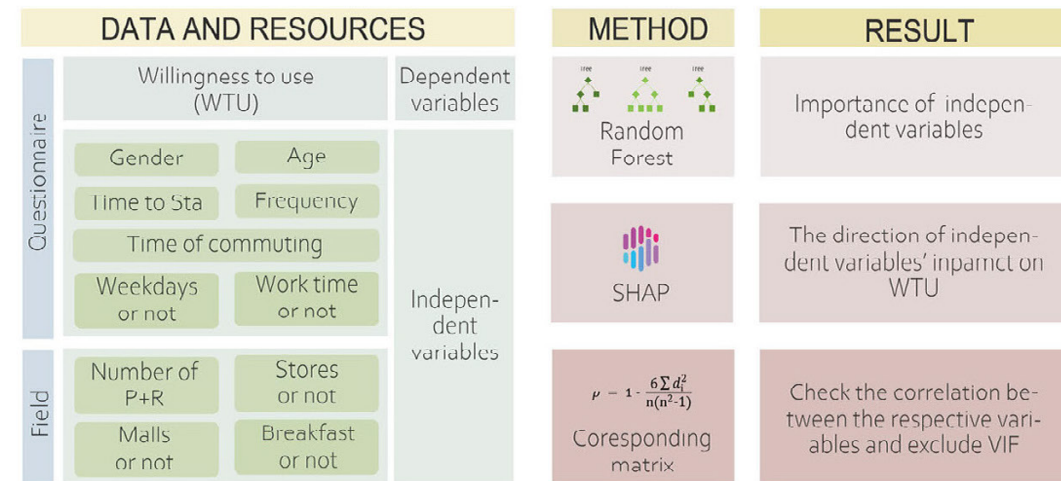


Fig.3-27 Flow of building WTU model

First, the Random Forest method was used to calculate the importance of these factors, and it was found that the time of subway commuting and the time needed to travel to the subway station were the two most important factors, and that built environment factors such as the number of P+R and the availability of breakfast stores also had an impact on WTU.

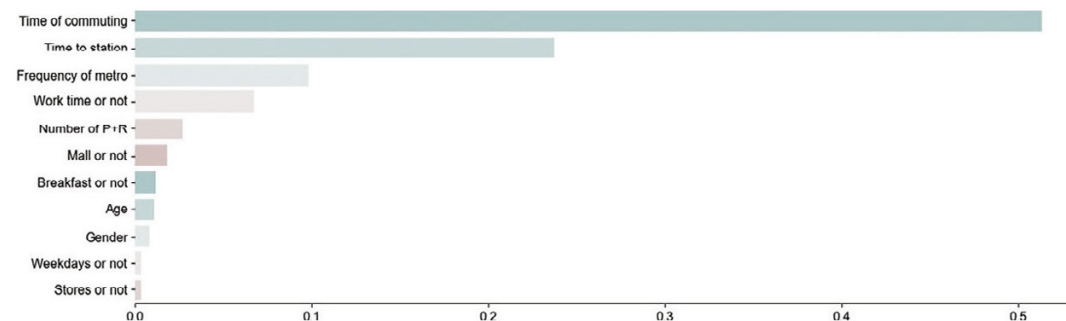


Fig.3-28 Importance ranking of independent variables

SHAP (SHapley Additive exPlanations) method was used to find that Time of commuting and Time to station have significant positive effects on the willingness to use P+R, number of P+R and whether there is a breakfast store are also factors that have positive effects on the WTU, while the dot of age and gender are mainly distributed around 0, indicating that the WTU is basically independent of age and gender.

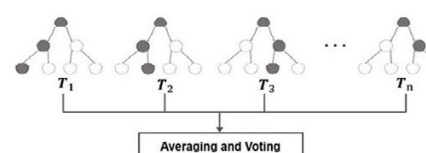


Fig.3-29 Random forest diagram



Fig.3-30 SHAP diagram

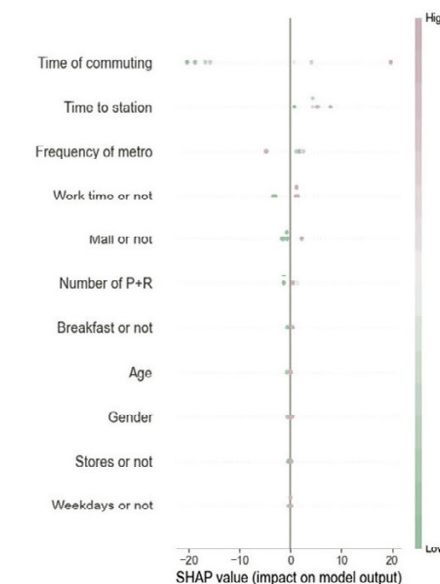


Fig.3-31 SHAP value for independent variables

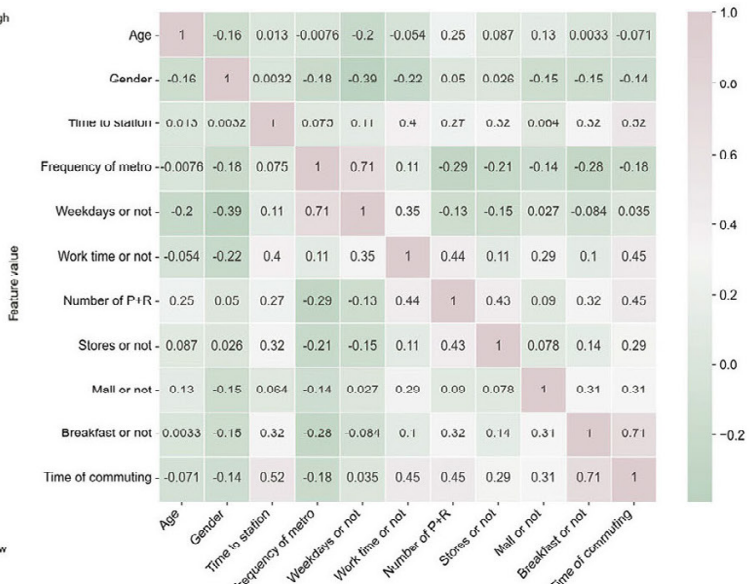


Fig.3-32 Corresponding matrix

To test the reliability of the model, correlation coefficient matrix was used. The correlation coefficient matrix was plotted using Spearman's rank correlation coefficient, which was calculated using the following formula:

$$\rho = 1 - \frac{6 \sum d_i^2}{n(n^2-1)}$$

The matrix of correlation coefficients plotted shows that the correlation coefficients of the majority of the independent variables are below 0.1, which is significant at the 90% level, so the results obtained using Random Forest with SHAP are generally reliable.

## Chapter 4. Optimal and Allocation Strategy

## SUMMARY OF ISSUES



The service boundaries of Park and Ride (P+R) facilities are not well-defined, which may lead to potential users questioning whether the service is suitable for their needs.

## Unclear service scope

## Delayed construction

The construction of some P+R facilities is behind schedule, with incomplete infrastructure that fails to meet current demands.

There is an unreasonable allocation of parking spaces for motor vehicles versus non-motor vehicles at P+R facilities, which could affect the efficiency and convenience of their use.



## Mismatch of vehicle parking spaces

## Insufficient pricing competitiveness

Compared to monthly parking options within the region, the majority of P+R facilities lack attractive pricing, thereby diminishing their appeal to commuting populations.







# Park Peacefully Transfer Rapidly

Park-and-Ride optimization improvement strategies

## Chapter 1 Interduction

## Chapter 2 Current policy and effect review

## Chapter 3 P+R use intention and influencing factors

## Chapter 4 Optimal and allocation strategy

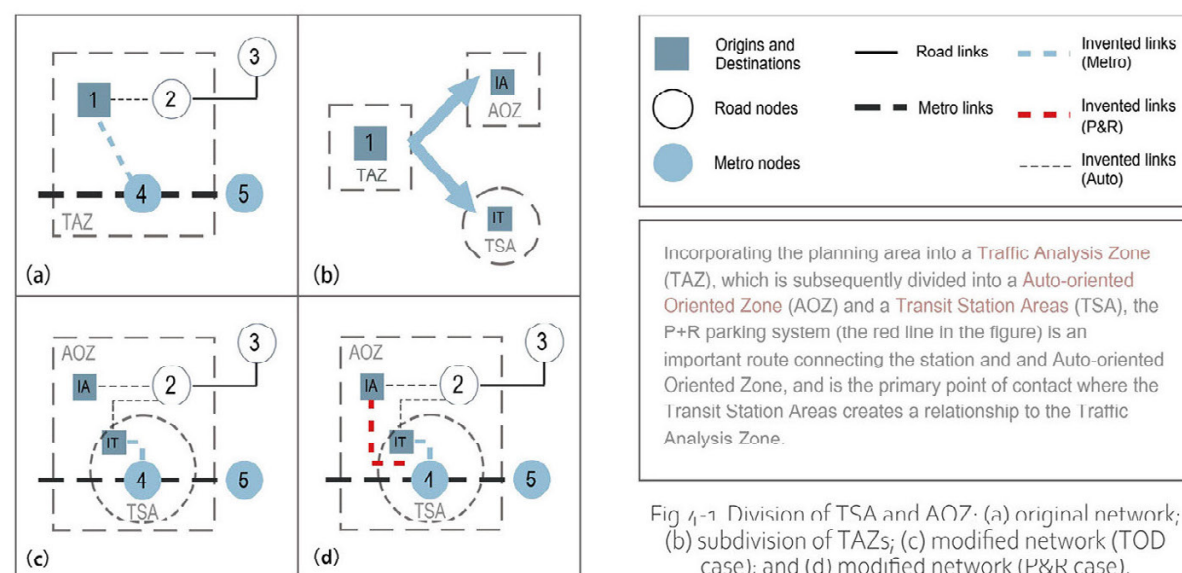
## Chapter 5 Appendix

### Accelerate the Construction of P+R Parking Lots

#### STRATEGY 1

To enhance urban mobility and reduce traffic congestion, it is imperative to accelerate the construction of P+R facilities. By expanding the availability of convenient and secure parking spaces at key subway and bus stations, the city can effectively reduce the volume of traffic in central urban areas.

Each additional P+R parking space has a positive effect on willingness to use P+R, attracting 105 car trips per month.



### Site Characteristics-Based Service Radius Rationalization

#### STRATEGY 2

Thiessen polygons are used to segment a region into multiple subareas based on proximity. Using subway station data, this method reveals that suburban stations have larger service radii and serve more people.

Delineating the service radius allows the planning department to forecast the number of parking spaces for P+R based on the number of people to be served, making up for the shortage of P+R parking spaces at a rate of 20 spaces per 1,000 people.

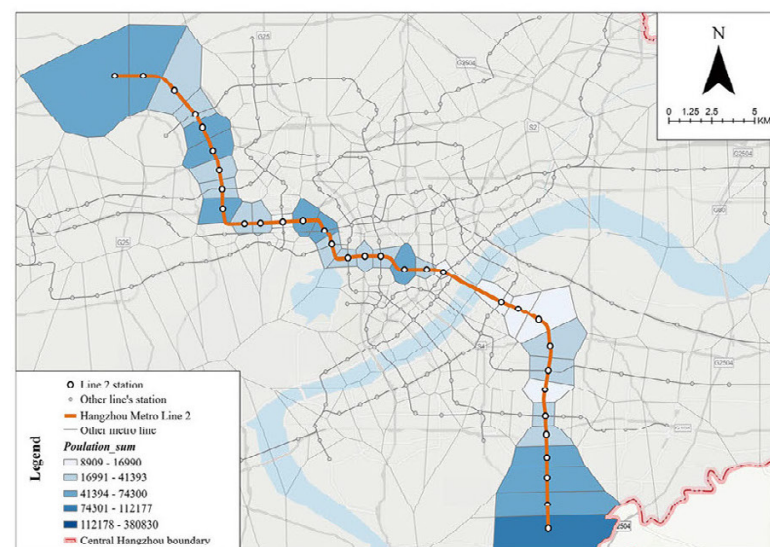


Fig. 4-2 Service area for each station

### Launch a Reservation System with Hangzhou City Brain

#### STRATEGY 3

Implementing a smart reservation system for P+R facilities, integrated with Hangzhou's City Brain, can significantly enhance the efficiency and user experience of the P+R service. This system would allow commuters to reserve parking spaces in advance, ensuring availability and saving time otherwise spent searching for parking.

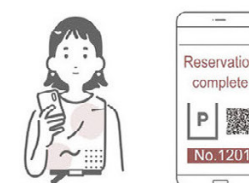


Make reservation on APP

Arriving within 15mins

If arriving on time

If arriving over time



### Directing Subway Stations When Parking is Full

#### STRATEGY 4

Consequently, for the terminal stations of the subway, parking spots are typically available before 8:15 AM. After this time, for every five-minute delay, commuters should proceed directly to the next subway station. With the Hangzhou City Brain, alternatives can be easily calculated when parking lots are congested.



### Rationalizing P+R Services by Site Characteristics

#### STRATEGY 5

When the driving time is less than 10 mins, users tend to choose non-motorized vehicles for travel.

Therefore, when a station is completely covered by orange, non-motorized vehicles should be primarily considered and configured at 40 per 1,000 population, and conversely, motorized parking should be primarily considered.

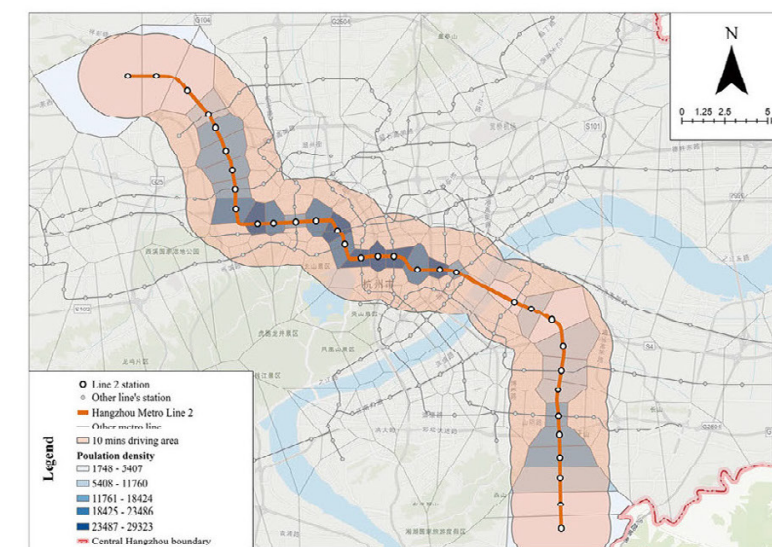


Fig. 4-3 10 mins driving area of each station





Chapter 5. Appendix

Questionnaire:  
Hangzhou P+R Utilization and User Experience Survey

Dear Respondent,

Hello! Thank you for taking the time to participate in our survey. We are members of the Zhejiang University College of Civil Engineering group focusing on "Utilization and User Experience Evaluation of Hangzhou's P+R System." This survey aims to understand your usage and experience with Hangzhou's Park and Ride (P+R) system. Your responses will be protected under the Statistics Law, kept strictly confidential, and processed with technical measures to ensure no negative impact on you. The survey may take some of your valuable time, and we appreciate your cooperation!

You may refuse to answer any questions you do not wish to answer. If you have any questions, please contact the survey team members.

A. Basic Information

A1. What is your age\_\_\_\_\_ ; Gender\_\_\_\_\_ ; Political affiliation\_\_\_\_\_ ;

A2. Your primary mode of transportation to the subway station is:

- A. Motor vehicle
- B. Electric bicycle
- C. Bicycle
- D. Walking
- E. Other

A3. The time it takes to reach the nearest subway station using your usual mode of transportation is:

- A. Less than 15 minutes
- B. 15-30 minutes
- C. 30-45 minutes
- D. More than 45 minutes

A4. [For respondents who chose A/B/C in A2] Your main purpose for going to the subway station parking lot is:

- A. To use P+R, then transfer to the subway
- B. Monthly parking, then transfer to the subway
- C. Just parking
- D. Other

A5. Do you understand Hangzhou's P+R (Park and Ride) and its policies?

- A. Yes
- B. Somewhat
- C. No

B. [For respondents who chose A in A4]  
P+R Usage Survey

B1. Your primary destination after arriving at the subway station is:

- A. Work
- B. Shopping and entertainment
- C. Tourism
- D. Other

B2. The frequency of using the parking facilities near the subway:

- A. Less than twice a week
- B. 2-4 times a week
- C. 5-6 times a week
- D. Daily
- E. Frequency varies significantly each week

B3. The main time period you use the parking facilities near the subway:

- A. Working hours (8:00-17:30)
- B. Non-working hours
- C. No specific time period

B4. The main days you use this parking facility are:

- A. Weekdays
- B. Weekends
- C. Throughout the week
- D. No specific days

B5. [For respondents who chose A in A2] [Multiple choices] Reasons for choosing to park near the subway and then transfer rather than driving directly into the city:

- A. Save on fuel costs
- B. Save time
- C. Other

B6. [For respondents who chose B/C in A2] [Multiple choices] Reasons for choosing to park near the subway and then transfer rather than driving directly into the city:

- A. Current transportation mode cannot reach the destination
- B. Save time
- C. Other

B7. [Multiple choices] Why did you choose P+R parking instead of monthly parking?

- A. Lower cost
- B. Convenience
- C. Unaware of monthly parking policies
- D. Other

B8. [Multiple choices] What problems do you think exist with the current P+R system?

- A. Parking spaces are often full and in a saturated state
- B. Parking system is not stable enough
- C. Lack of auxiliary functions such as vacancy inquiry and car search system

- D. Using Hangzhou Citizen Card is not convenient enough
- E. The distance to transfer to the subway is too long
- F. High cost
- G. Other

B9. Your rating of the Hangzhou P+R system (1 is the lowest, 5 is the highest): \_\_\_\_

C. [For respondents who chose B in A4]  
Monthly Parking Users Survey

C1. Are you aware that this parking lot belongs to a P+R parking lot?

- A. Yes
- B. No

C2. [Multiple choices] Why did you choose monthly parking instead of P+R parking?

- A. Convenience
- B. Lower cost
- C. P+R is difficult to operate
- D. Other

C3. The current P+R policy's daily cap price is 15 yuan. At what price would you choose P+R instead of monthly parking?

- A. 12 yuan
- B. 10 yuan
- C. 8 yuan
- D. 6 yuan

D. [For respondents who chose C in A4]  
Parking-Only Users Survey

D1. Are you aware that this parking lot belongs to a P+R parking lot?

- A. Yes
- B. No

D2. Are you a monthly user of the parking lot?

- A. Yes
- B. No

D3. [Multiple choices] The main reasons you park in this parking lot are:

- A. No nearby parking lots
- B. Low cost
- C. Habit of using this parking lot
- D. Other

E. Open-ended Questions

E1. Do you have any other comments or suggestions for Hangzhou's P+R system?







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### Chapter 5. Appendix

#### In-depth interview 1

Interview subjects 1: white-collar workers in the Xiaoshan area who use the park-and-ride (P+R) system to commute to the uptown area every day. We interviewed this interviewee on a weekday after hours at the Chaoyang Station located at

Q: Thank you very much for agreeing to our interview. Are you familiar with the Park and Ride (P+R) system?  
A: Yes, I am quite familiar with it. I use it daily to drive to the subway station and then transfer to the subway to go to work in the downtown area.

Q: How long does it take you to drive from your home to the subway station?  
A: It takes about 15 minutes. Fortunately, the traffic is usually smooth on the way from my home to the subway station.

Q: How often do you use the P+R system?  
A: I use it every day. I find it a convenient way to get into the city center, especially during peak hours.

Q: How long does it take to get to work after transferring to the subway?  
A: It takes about 30 minutes to reach the office in the downtown area after switching to the subway.

Q: What is your assessment of the current P+R system?  
A: Overall, I think it's pretty good. It really saves me a lot of time, especially in avoiding traffic congestion in the city center.

Q: What do you think are the advantages of the P+R system?  
A: The main advantages are convenience and efficiency. I can avoid congestion and high parking fees in the city center. Additionally, it is environmentally friendly, reducing the use of private cars and carbon emissions.

Q: What do you think are the drawbacks of the P+R system?  
A: Firstly, sometimes there are not enough parking spaces available, especially during peak work hours. Secondly, the payment system sometimes malfunctions, which is inconvenient. I hope there could be more parking spaces and a more stable payment system.

Q: Thank you very much for sharing your valuable opinions! I wish you a pleasant life.

#### In-depth interview 2

Interview subjects 2: residents living in Yuhang District who use the park and ride (P+R) system to travel to the city on weekends. We interviewed this interviewee on a weekend morning at 10:00 a.m. at the Liangzhu station.

Q: Thank you for agreeing to our interview. Do you often use the Park and Ride (P+R) system to travel to the city for tourism?  
A: Yes, I use it almost every weekend. Driving directly into the city is too troublesome and parking is expensive and inconvenient.

Q: Could you explain why you choose not to drive directly to the city center?  
A: Driving directly would mean dealing with heavy traffic and high stress levels, especially during peak tourist times. Additionally, finding affordable and convenient parking in the city center can be very challenging.

Q: How long does it take you to get from your home to the subway station?  
A: About 20 minutes. The distance isn't far, but sometimes there is some traffic.

Q: How has your experience been using the P+R system? Does it meet your needs?  
A: Overall, it's quite good. I mainly use it to avoid congestion and high parking fees in the city center. With the P+R system, I can enjoy my weekends more relaxedly.

Q: How long does it usually take to travel from the subway station to the tourist spots in the city?  
A: It takes about 30 to 40 minutes, depending on the specific location I am going to.

Q: What do you think are the advantages of the P+R system?  
A: Its biggest advantages are convenience and cost-effectiveness. I can save a significant amount of parking fees and also reduce environmental pollution. Moreover, the subway connects to multiple tourist attractions, which is very convenient.

Q: Have you ever felt that the cost associated with the P+R system is too high?  
A: Not really. When compared to the costs of city center parking and the stress of driving there, I find the P+R prices to be reasonable. It's a good balance of cost and convenience.

Q: What problems have you encountered using the P+R system?  
A: Sometimes the parking spaces are also tight on weekends, especially during holidays. As a result, I sometimes have to drive long distances to find a parking space, or am forced to choose to drive into town



Q: Do you have any suggestions or expectations to address these issues?  
A: I hope that more parking spaces can be added, especially on weekends and holidays. Also, it would be better if there could be more frequent subway services and more timely information updates.

Q: Thank you very much for participating in our survey. We hope your future travel experiences are even more smooth and enjoyable!

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