Exploration and planning of water bus in urban new district——Taking Hangzhou Science and Technology City as an example

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Abstract: In recent years, as one of the components of urban public transportation, water bus has developed rapidly in cities whose water systems is rich. Based on the background of the project of “Future Technology City” in the “13th Five-Year Plan” of Hangzhou, combined with its regional characteristics, this paper proposes a new model of bus —— water BRT (water bus), which analyzes and summarizes the conceptual characteristics of water BRT and framework of system. According to the status of regional traffic and characteristics of module in the Science and Technology City, the paper forecasts the demand of passenger flow, analyzes the setting of the waterway and terminal, comprehensively evaluates the selection and operation of the ship, and finally proposes a reasonable programme of planning.

1. Preface
Along with the development of the city, many large and medium-sized cities are not satisfied with the existing regional development model, and have explored new development models for their regional characteristics. At present, “Waterway Rejuvenation” is a major feature in the planning of Hangzhou Science and Technology New Town. This paper will talk about the development of water BRT in the new urban area.

2. Concept and characteristics of water BRT

2.1 Concept of water BRT
The water BRT is rapid transit on water, which is part of the urban public transportation system. Its main mode of operation is to use the carrier on the water to run quickly on a dedicated route.

2.2 Characteristics of water BRT
The characteristics of water BRT are mainly reflected in the mode of transport, service objects and safety features.

   (1) Characteristics of carrying mode
   Systems of Conventional BRT use multi-line hybrids with dedicated road rights; while on-water BRT systems are primarily in specific river systems that are not interfered with by ground buses and other means.

   (2) Characteristics of service objects
   The functional orientation of the core area of Hangzhou Future Science and Technology City
includes: technology research and development, public services, fashion residence and leisure tourism, etc., and its service targets are mostly biased towards middle and high-level business people.

3. Characteristics of security features
The installation of hardware facilities for systems of terrestrial BRT has become more complete and less affected by climatic conditions. The effect of the BRT on the water is greater, and the adverse weather conditions affect the travel efficiency and service to a certain degree.

3. Framework of water BRT system
The framework of the water BRT system is mainly composed of terminals and routes that bear the role of different transportation tasks.

3.1 Various types of terminals
(1) Hub terminal: refers to a large hub terminal for water BRT, which means that the traffic demand is large or the geographical position is important, and there are many routes originating or stopping, which can be connected with the rail transit.
(2) Transfer Terminal: Generally speaking, the transfer terminal should have 3 or more routes, and it has high accessibility and can achieve good traffic transfer with various modes of transportation.
(3) General Wharf: Refers to a small dock that is temporarily docked at a water BRT or other passenger and cargo transfer station.

3.2 Various routes
(1) Route of peak commuter: It is mainly operated during peak hours. The use of fast water traffic channels to share the traffic flow of some urban areas can help solve the commuting traffic pressure in the peripheral area and the central area.
(2) Route of conventional commuter: It has the service characteristics of fixed-point timing, and delivers passengers to the destination by means of scheduled and fixed lines, mainly serving the needs of floating residents along the line.
(3) Route of leisure and transportation: The main function is to strengthen the transportation links of the main sightseeing spots on both sides of the river, and integrate the function of transportation with the function of leisure and sightseeing.

4. Urban regional background and feasibility analysis of the project

4.1 Overview of water bus
In 2004, Hangzhou opened a water BRT with functions of transportation and sightseeing, which played an active role in optimizing the urban transportation network. The operating vessels are mainly passengers ships, and the sightseeing tour mainly consists of barges. Currently, Hangzhou has eight major lines which are operating.

![Figure 1. Current status of water BRT operation in Hangzhou](image)

The current planning area is the core area of Hangzhou Future Science and Technology City. The
east site is adjacent to the ring highway and Xixi National Wetland Park, the west side is the industrial park, the south side is the Xianlin town, and the north side is the future technology city long-term industry and educational area.

Figure 2. The division of technology city

4.2 Feasibility study
The layout of the water BRT in the urban area is restricted by factors such as the width of the channel, the conditions of the water depth and the clearance of the bridge across the river, and the navigation conditions of the area need to be investigated and analyzed.

1) Main river channel: Yuhangtang River starts from Wuhang Town in Wuhang Town, east to Daguankangjia Bridge and enters the Beijing-Hangzhou Grand Canal. The river width is about 55m and the river bottom elevation is -1m~-1.5m. The Xianlin port starts from the Yuhangtang River in the north and the Xianlin in the south. The width of the river is about 50m and the elevation of the river bottom is -1m.

2) Secondary rivers: In addition to the Heguo Port, Fangjiaqiao Port, Gujiaqiao Port and Tianzhuqiao Port on the south side, there are four other ports in the planning area, namely Heguo Port, Hongwei Port, Wangqiao Port and Yaojia Port. The main river channel is a structure of "well" with a river width of 20~30m and a river bottom elevation of -1m~0.5m. Therefore, Yuhangtang River, Xianlin Port and Tongyi Port are the main channels in the area.

Figure 3. Water system of Science and Technology City

5. Status analysis and demand forecast of Science and Technology City

5.1 Analysis of the current situation of Science and Technology city’s traffic
(1) Public transportation services in the future science and technology city need to be improved
The picture below shows the current traffic rate and satisfaction of the traffic.

(a) Future technology city current travel sharing rate
(b) Public traffic satisfaction survey

Figure 4. Analysis of the current situation of the city's traffic

According to the above picture, it can be seen that the public transportation services in the Science and Technology City need to be improved, mainly reflected in the following two points.

a. The bus travel rate is low. According to the sample survey’s results of residents in the planning area, the current proportion of public transport trips reached 27.5%, and 28% of the talents in the commuting mode were willing to take public transportation in the commuting mode.

b. Bus satisfaction is not high. According to the satisfaction survey of residents public transportation’s status, the public transportation's bus satisfaction is only 53%, and up to 47% of residents are not satisfied with the current bus service.

(2) Great connection with urban traffic, but the traffic structure is single and far away

Investigating the way of scientific and technical personnel commuting, we can find that many middle-income and high-income people such as entrepreneurs, managers, and R&D personnel in the Science and Technology City have long travel distances, and motorized travel has become an inevitable choice for employees to travel. Especially during the morning rush hour, the proportion of motorized travel from the main city to the future technology city reached 78%.

Figure 5. Commuting options of technology talents

5.2 Demand forecast
1. Forecast of total traffic generation
   (1) Regional division

The future technology city will be divided into four larger traffic cell units according to the important attributes of the area, and the total traffic generation’s amount of the area will be calculated.
(2) Model selection
This paper uses the method of original unit for prediction. The average amount of traffic generated by the resident population or the employed population, or the average amount of traffic generated by the land area or unit office’s area for different purposes. The prediction model is as follows:

\[ P_i = E_i \times Z_j \]  

In the formula:
- \( P_i \): Community traffic attraction (occurrence);
- \( E_i \): the original unit of personal transportation attraction (occurrence);
- \( Z_j \): The number of people living (employed) in the community.

(1) Results of prediction (Unit/10000 person-times)

| OD  | 1   | 2   | 3   | 4   | total |
|-----|-----|-----|-----|-----|-------|
| 1   | 4.83| 1.81| 0.2 | 0.16| 6.9   |
| 2   | 1.75| 3.43| 0.18| 0.04| 5.4   |
| 3   | 0.23| 0.17| 0.75| 0.09| 1.2   |
| 4   | 0.1 | 0.01| 0.07| 0.18| 0.3   |
| total| 7   | 5.4 | 1.2 | 0.4 | 14.00 |

Current travel generation \( T = 140,000 \) (times/day)
Current resident population \( N = 30.6 \) (million)
The resident population in the future is \( M = 30.6 \times (1 + 18.6\%) = 36.3 \) (ten thousand people)
The original unit of resident population \( T/N = 0.46 \) (time/day·person)
Future generation traffic volume \( X = M \times (T/N) = 16.7 \times 10,000 \) times/day
(Note: According to the results of the Yuhang resident survey over the years, the average population growth rate is 18.6% to predict the population in the future.)

2. Traffic distribution forecast
(1) Model selection
The traffic distribution prediction uses the method of unconstrained gravity to calibrate the model parameters. The model is as follows:

\[ q_{ij} = \alpha \frac{P_i P_j}{d_{ij}^2} \]  

In the formula:
- \( q_{ij} \): traffic distribution between i to j;
- \( d_{ij} \): the distance from the i to the j;
- \( \alpha \): the coefficient to be calibrated;
\( P_1 \): the number of people in the community;
\( P_2 \): the number of people in the community.

The calibration method is obtained by using the method of least squares to obtain the calibration coefficient, \( \alpha = 0.183 \), and the calculated distribution traffic volume is obtained.

### Table 2. Traffic distribution

| O | 1   | 2   | 3   | 4   | Total |
|---|-----|-----|-----|-----|-------|
| 1 | 5.845 | 2.111 | 0.213 | 0.181 | 8.350 |
| 2 | 2.001 | 4.126 | 0.185 | 0.090 | 6.402 |
| 3 | 0.310 | 0.204 | 0.758 | 0.120 | 1.392 |
| 4 | 0.161 | 0.078 | 0.107 | 0.210 | 0.556 |
| Total | 8.317 | 6.519 | 1.263 | 0.601 | 16.7 |

According to the distribution of data in the table, the traffic flow in the Science and Technology City is mainly distributed within the station. At the same time, the relationship between Block 1 and Block 2 is relatively close, accounting for the main part of the traffic volume between the blocks.

### 6. Layout of route and site

#### 6.1 Site and dock classification

The terminals can be divided into three types according to different functions and levels, namely the water distribution center, the hub terminal, and the conventional terminal. The conventional terminal is the lowest level of transportation infrastructure, and the passenger flow is not large; the hub terminal mainly assists in connecting passenger routes and is an important node of the city's public transportation hub; The water distribution center is an important transfer node which connects the public water transportation system with the city's main transportation hub.

#### 6.2 Traffic status analysis of area

(1) Distribution of road systems

![Figure 7. Road system distribution](image)

The road network in the Science and Technology City area is mainly distributed in the shape of “well”. The main road and the secondary road are the main roads, and the secondary road network is dense.

(2) Layout of public transportation hub site
The density of the bus hub is not high, and the distribution location is mainly along both sides of the track line under construction, connecting the traffic community 1 and the traffic community 2. On both sides of the track, it is the main water system trend in the area, and the Yuhangtang River, an important water system hub, is located nearby. The establishment of a water terminal hub can form a connection with the two transfer modes of rail and bus.

6.3 Route selection

The river system of Hangzhou Science and Technology City is developed, the river channel in the northern area is wide, and it is the carrier of the main water main road. The water system in the southern leisure area and living area is developed, mostly composed of narrow river channels, mainly for the daily life of the residents. The picture below shows the river distribution.

According to the distribution of rivers and road networks, some of the main roads are selected as the operation route of the water BRT in the area. The east-west river channel on the north side is the Yuhangtang River, and the north-south main river channel is the Xianlin lane.
6.4 Hub terminal site selection
Take the Cangqian Station as an example. The terminal has a radiation radius of 1000m and there are 8 bus stops around the terminal. By setting up the site here, the transfer mode of the dock site and the land bus stop can be diversified, forming a good transfer and attracting more passengers. The small wharf is equipped with a radiation radius of 500m, which is arranged substantially evenly in the river network. It is used as a regular dock for mid-way transfer to serve the needs of small-scale passengers.

The 1000-meter radius is used as the radiation area of the large terminal such as Cangqian Station and Hangzhou Normal University, and the 500-meter radius is used as the radiation area of the remaining small terminals. The number of bus stops in the radiation area is arranged as follows, which basically fulfill the needs of residents around the main river channel.

| number | pier     | Number of bus stops |
|--------|----------|---------------------|
| 1      | Cangqian | 9                   |
| 2      | Changer  | 2                   |
| 3      | HNU      | 9                   |
| 4      | Lujiaqiao| 1                   |
| 5      | Xiuguqiao| 9                   |
| 6      | Yingyuetai| 3                   |
| 7      | Tielingqiao | 5               |
7. Selection and operation of ship

7.1 Frequency of the ship

The determination of the ship's frequency can be compared with the conventional bus dispatching method, and the scheduling is planned according to the travel time characteristics of the passenger flow. The ship's interval value is controlled within a certain range, that is, the minimum limit condition and the maximum constraint condition.

(1) Minimum restrictions

\[ T \geq \frac{3600}{C_v} \]  

In the formula:
- \( C_v \): Terminal docking capacity, vehicle/hour
- \( T \): Interval of time of departure

(2) Maximum constraint condition

\[ T \leq 2T_w \]  

\( T_w \): Maximum waiting time for passengers
- \( T \): Interval of time of departure

The range of the ship's interval is:

\[ \frac{3600}{C_v} \leq T \leq 2T_w \]  

The departure schedules of several water BRT that have been completed in Hangzhou are shown in the following table:

| line | Line 1 | Line 2 | Line 3 | Line 4 | Line 5 | Line 6 | Line 7 | Line 8 |
|------|--------|--------|--------|--------|--------|--------|--------|--------|
| Number of sites | 3 | 10 | 11 | 5 | 10 | 4 | 8 | 6 |
| interval (min) | 25~30 | 20~70 | 150 | 180 | 265 | 90~120 | 30 | 30 |

According to the departure schedule of Hangzhou BRT and the expected travel time of residents, as the speed of the ship increases and the single-load capacity decreases, the interval between departures should be shortened as much as possible. Referring to the passenger demand of the existing line and its corresponding ship frequency, the ship frequency of the main river channel is set at 20 min, and the branch channel is flexibly adjusted according to demand.

7.2 Carrier

The type of water BRT vessel is roughly divided into 30 passenger seats and 60 passenger seats. The speed of the boat is relatively stable. The combination of two types of carriers, yacht and bus, can effectively improve the efficiency of operation in a specific area. The ship type characteristics are shown in the following table:

| Type of ship | Number of passengers | Length (m) | Width (m) | Speed (km/h) | Draught depth |
|--------------|----------------------|------------|-----------|--------------|---------------|
| Small yacht  | \( \leq 8 \)         | \( \leq 10.5 \) | 1.6~2.2   | 30~74        | 0.9~1.7       |
| Medium yacht | 8~12                 | 10.5~18    | 2.6~5.4   | 30~50        | 1.1~1.2       |

The traffic flow between the residential area 1 and the residential area 2 is relatively large, and the Yuhangtang River passing through it is the main river channel of the area, so the line can be set up with several large-scale water BRT that meet the large traffic volume. At the same time, in the case of navigational conditions, some small and medium-sized yachts will be added to form a complementary part of the area and the navigation channel to increase the efficiency of traffic.

7.3 Docking berth

The number of berths docked at the dock depends on the traffic demand and the geographical
characteristics. According to the above analysis of the traffic four-cell OD table, the traffic flow between the area 1 and the area 2 is large.

Figure 12. Levels of dock berths

Therefore, during the layout of the docking berth, a large central terminal (distribution center) is set up at the Cangqian dock and the Tielingqiao dock as the hub for the water BRT at the center of the Yuhangtang River. Other terminals such as Changer Road Dock, Hangzhou Normal University Dock and other terminals with a service radius of 1000 meters serve as transit hub terminals. The remaining 500-meter service radius of the small terminal serves as a regular terminal with a small number of berths for temporary stops and passengers.

8. Analysis and summary

The operation of the water BRT will bring a variety of effects to the new area of the Science and Technology City and play a variety of roles. (1). Undertaking part of the passenger pressure. Water BRT will attract a considerable part of passenger flow in short-distance operations, and it will become one of the alternative modes of travel for the passenger traffic corridor with tight land resources. (2). Supporting the development along the river bank. The river bank in the new urban area will become a key development area, forming a boundary between urban regional transportation and water transport culture. (3). Forming a convergence tool for multiple modes of transportation in urban areas. The complete waterway route will be connected with various modes of transportation such as roads, tracks and buses in the city to jointly build a complete public transportation system.

References

[1] Li F, Ji L. Analysis on the Development Status of Water Bus at Home and Abroad[J]. Pearl River Water Transport, 2016, (10):32-33.
[2] Wang B, Sun C, Bi E G. Preliminary study on the water bus system planning in the coastal area of Shenzhen[C]. //Proceedings of the 2011 Annual Conference of China Urban Transport Planning and the 25th Symposium. 2011:900-908.
[3] Yu Y C, Li H Y. Exploration and practice of developing water bus in central cities —— Take Guangzhou as an example[J]. Transportation and Transportation (Academic Edition), 2015(02):110-113.
[4] Du Y G. Innovative design of the site project of Hangzhou “Water Bus” [J]. Municipal technology, 2009, 27 (02):91-94.
[5] Liu Y P. Analysis and Development of the Demand for Water Bus in Guangzhou[D]. Sun Yat-Sen University, 2009.
[6] Luo L X, Yan P Y, Liu Z Q, Qiu X Y. Predictive study of the passenger flow of the test of the water bus in Guangzhou[J]. China Water Transport, 2010, 10 (07): 78-80.
[7] Fan J, Shi J H, Pan T. System planning for urban water bus——Take Suzhou as an example[C]. //Proceedings of the China Metropolitan Transportation Planning Seminar, China Urban Transport Planning 2010 Conference and the 24th Symposium. 2010: 599-606.
[8] Jiang C. Research on the Development Model and Planning Method of Water Bus in Chinese
Cities[D]. Southeast University, 2013.