Original research paper

~~Reviews~~

Rapid transit mode selection for urban transportation corridor--A case for Zhenjiang new district

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Abstract

With the expending of urban space, many new districts emerged outside the central city; kinds of these large cities face new traffic problems while the traffic demand between new district and central city increased. Under the limited road resources, most cities committed to rapid transit developments. Since there exist several kinds of rapid transit modes to be selected for an urban transportation corridor, the government or the decision making department should properly chose the most suitable rapid transit mode based on its actual demand. This paper provides a quantitative method to evaluate the comprehensive utility of different rapid transit modes, which involves nondimensionalize utility matrix as well as binary fuzzy contrast method to determine weight coefficient. Accordance with the principle of comprehensive utility maximization, the quantitative methods proposed in this study can be used as a decision-making reference for selecting rapid transit mode within

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urban transportation corridor. The approaches is illustrated by a case in Zhenjiang new district in china, and proved to be feasible and effective.

Keywords:

Transportation corridor; Rapid transit system; Mode selection; nondimensionalize utility; Binary fuzzy contrast method; Case study;

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1 Introduction

With the continuous development of urban population and social economy, urban space has gradually expanded, many large cities gradually emerged a series of new districts around the central cities. These urban new districts have alleviated the traffic, employment and housing pressure of the central cities at a certain extent, but have also triggered new traffic problem: the corridor connecting urban new district and the central city is getting more and more congested. Experience has proved that, simply increased the supply of road resources cannot meets the increasing traffic demand between urban new district and central city, it even bounds to cause traffic congestion, environmental pollution and waste of traffic resources. In order to cope with the traffic problems between urban new district and central city, many cities around the world are committed to the development of rapid transit systems with characteristic of large or medium capacity, rapid operation speed and environmental friendly, such as urban rail transit(URT); modern tram(MT); bus rapid transit(BRT) and personal rapid transit(PRT). All of these rapid transit systems vary very much in technical parameters such as capacity, construction cost and other related operation and construction indicators. Decide and choose the most suitable rapid transit system based on its actual situation is the primary task for the government.

However, judging from the practical application, most cities lack of reasonable decision making basis when choosing rapid transit system, they just blindly follow the trend of building URT, BRT or MT. Inappropriate transit mode would results in ineffective transportation; poor economic performance, even in some cases, ending with dismantle reconstruction (such as Chongqing Gaojiu Rd. BRT), all of these definitely waste a large sum of economic resources.

In order to provide scientific and reasonable decision-making basis for the relevant departments, academic researchers have done a lot of researches on decision making and mode selection. Zietsman et al. (2006) considered the economy investment and social benefits (such as social equity, safety and the environment), and put forward the multi-attribute utility theory to determine the traffic corridor route planning. For transportation mode configuration issues of the urban area, Yang Min et al. (2006) regarded the transportation mode decision-making process as an input-output problem, and established

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the decision-making evaluation model by data envelopment analysis(DEA) and analytic hierarchy process(AHP). Lu Zhenbo et al. (2008) constructed a logit model based on data survey and analysis, and adopted the passenger sharing rate as the basis for the choice of transit mode.

As to the traffic mode configuration problem between central cities and satellite cities, Ma Shuhong et al. (2009) considered the traffic, economic, social resources and environment factors, provided entropy weight decision method combined with superiority weakness opportunity threats (SWOT) analysis; Su Youmei (2010), Yan Jing (2013) both used fuzzy evaluation method to get the weight, and made use of gray correlation degree method to solve the optimal evaluation model. On the issue of determine the dominant traffic mode in the passenger corridor of metropolitan area, Guo lichao et al. (2015) proposed a comprehensive evaluation model based on variable weight synthesis and AHP. In addition, the impact of rapid transit system to the social economic benefits and property value can also be used as a basis for transport mode decision-making(Glen Weisbrod et al. 2016, Corinne Mulley et al. 2016, Taotao Deng et al. 2016). Based on the existing researches, this paper focuses on the rapid transit mode selection for a typical transportation corridor, and provides a quantitative method to evaluate the comprehensive utility of different rapid transit modes, which involves nondimensionalize utility matrix and binary fuzzy contrast method to determine weight coefficient. The comprehensive utility can be used as a decision-making reference for selecting rapid transit mode within urban transportation corridor.

The paper is structured as follows: section 2 gives a brief description of the major rapid transit mode around the world; section 3 focuses on the methodologies in the paper; section 4 and 5 illustrated and discussed the above methodologies in Zhenjiang new district in china; the final section concludes the paper and discusses recommendations for future studies.

2 Description of major rapid transit systems

So far, there are many rapid transit systems around the world, and roughly can be divided into four classes: Urban Rail transit, Modern tram, bus rapid transit as well as personal rapid transit.

2.1 Urban Rail Transit

Urban rail transit usually refers to the urban public transport systems with multi-section marshaled vehicles running on fixed rails, and generally powered by electricity. It provides large-capacity service, and is one of the most common types of rapid rail transit all over the world. According to the different axle weight, urban rail transit can be divided into subway and light rail.

(a) Subway (b) Light rail

2.2 Modern Tram

Modern Tram is electric-driven and medium-capacity transit system running on fixed rails. According to the different travel system, modern tram can be divided into two standard systems: steel wheel system and rubber wheel & rail system. It is one of the most popular rapid transit systems in the United States and Europe, and an emerging one in China because of its ability to operate in various roadway conditions and its lower capital cost compared to urban rail transit systems. There are about 300 cities around the world with trams.

(a) Steel-wheeled transit. (b) Rubber wheel transit source: image.so.com

2.3 BRT

BRT is a new type of public transit system which is based on the conventional public transportation, running on road network, and combines with modern new vehicle technology. It enjoys certain priorities (such as bus lanes and setting up the bus signal priority, etc.).The BRT system is established in a lot of cities in the world like Curitiba in Brazil and the New York in the United States, Large and medium-sized cities such as Changzhou, Xiamen, etc., also have been established since 2008. Compared with regular buses, BRT has bigger capacity, faster speed, and better punctuality.

Fig.~~ure~~ 3. BRT in Changzhou (source: image.so.com)

2.4 PRT

Personal Rapid Transit (PRT) is a personalized transportation system. It is computer-controlled, so does not require any driver. Wang Shusheng (2011) mentioned that PRT runs on exclusive rail network, and is driven by clean energy. By the number of passengers, this system includes both the small and the large type of vehicles, the smaller type of vehicles are called PRT, usually containing 6-12 peoples per car, while the larger ones, called GRT, accommodate 12-60 peoples per car. This system runs on call, so no time is wasted on transferring and waiting. It provides real-time, all-day and door-to-door services. Such convenience of this system and the light weight (about 500kg) of its vehicles guarantees its flexibility. Its controlling system can reduce the headways to as short as a couple of seconds, thus minimize the waiting time of passengers with a service close to elevators. Meanwhile, the system features its low carbon emissions – nearly zero, and low noise. Scale manufacturing can best reduce the construction cost of this system. Compared to traditional transportation means like regular buses and urban rail transits, PRT provides more capacity and better financial returns, which makes it a better choice in urban transportation systems.

~~(a)~~ ~~(b)~~

(a) PRT vehicle **(b) GRT vehicle**

PRT is now in operation in Heathrow Airport in London, Masdar City, United Arab Emirates and Suncheon, South Korea. PRT in London's Heathrow airport is a 2.4-mile, 3-station, 21-vehicle system

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connecting Heathrow's new Terminal 5 to the business car park a mile away. The system opened to the public in spring 2011. Suncheon opened a 40-vehicle system of 6 miles in 2014. The first PRT in urban area in China is planned to be built in Guangming District, Shenzhen.

3 Methodologies

3.1 Problem *description*

Assuming that there is a transportation corridor between central city and urban new district, and it needs a rapid transit system to support its gradually increasing traffic demand, m stands for the number of rapid transit modes to be selected, and n stands for the number of selected decision-making factors such as transport capacity and level of service etc.

Suppose M is an $m \times n$ initial matrix with its element x_{ij} represents the technical parameter of the j-th factor of the i-th rapid transit mode. Shows as Eq.(1):

$$M = \begin{bmatrix} M_1 \\ \vdots \\ M_m \end{bmatrix} = \begin{bmatrix} x_{11} & \cdots & x_{1n} \\ \vdots & x_{ij} & \vdots \\ x_{m1} & \cdots & x_{mn} \end{bmatrix}, \ i = 1,2,3 \cdots m, \ \ j = 1,2,3 \cdots n. \quad (1)$$

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The problem is, with the above decision-making factors and the initial parameter matrix, how to choose the most suitable mode for the transportation corridor, and what's the basis for decision making.

3.2 Comprehensive utility function

Utility is used to reflecting the quality for each factor, and usually the utility is closely related to its technical parameters. In a decision making process with more than two considering factors, the comprehensive utility represents the comprehensive quality, in this research, F is a comprehensive utility vector for several transit modes to be selected, $f_1, \cdots f_m$ separately stands for comprehensive utility value for each mode. F is normally positive correlation with initial parameter matrix M, see Eq.(2):

$$F = [f_1 \quad \cdots \quad f_m]^T, \ F \propto M \quad (2)$$

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Take no account of the relative importance of each indicator, we can simply regard the sum of every technical parameters as the comprehensive utility, see Eq.(3):

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$$F = [f_1 \quad \cdots \quad f_m]^T = [\sum_{j=1}^{n} x_{1j} \quad \cdots \quad \sum_{j=1}^{n} x_{mj}]^T \quad (3)$$

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However, the dimension of selected decision-making factors usually varies wildly, so in order to get the comprehensive utility value; we should firstly carry out the process of nondimensionalization.

We normalized each decision-making factor and get a nondimensionalize matrix $\bar{M}$。 see Eq.~~(~~4~~)~~ and Eq.~~(~~5~~)~~:

$$\bar{M} = \begin{bmatrix} \overline{M_1} \\ \vdots \\ \overline{M_m} \end{bmatrix} = \begin{bmatrix} \overline{x_{11}} & \cdots & \overline{x_{1n}} \\ \vdots & \overline{x_{ij}} & \vdots \\ \overline{x_{m1}} & \cdots & \overline{x_{mn}} \end{bmatrix}, \ \overline{x_{ij}} = \frac{x_{ij}}{\sum_{i=1}^{m} x_{ij}} \quad (4)$$

Under that way can we sum up the parameters of each factor and reach the comprehensive utility. So Eq.~~(33)~~ then can be adjusted to Eq.~~(~~5~~)~~ as follows:

$$F = [\sum_{j=1}^{n} \overline{x_{1j}} \quad \cdots \quad \sum_{j=1}^{n} \overline{x_{mj}}]^T \quad (5)$$

Furthermore, the relative importance of each factor varies from each other, for a more rational reflection of the comparative importance of the selected factors, we set a relative weight coefficient vector W, in which W_j stands for the relative weight coefficient of the j^{th} ~~j-th~~ factor.

$$W = [w_1 \quad \cdots \quad w_n], j = 1,2,3 \cdots n \quad (6)$$

So, the comprehensive utility function in the paper should be formed as Eq.~~(~~7~~)~~:

$$F = \bar{M} \cdot W^T \quad (7)$$

The use of comparative weights is a controversial issue because it opens up the analysis to a certain amount of subjectivity (Zietsman et al. 2006), but it could serve as an important tool to allocate the relative importance of the selected factors by decision makers.

3.3 Binary fuzzy contrast method to determine Weight coefficient

There are many methods to determine the weight coefficient of the factors, such as ring ratio score method, geometric mean score method, entropy technique method, but all these methods are either too complicate to deal with or inaccuracy with large amount of subjectivity. Considering that, it is easier for one to deice the importance within two factors at once; this paper provides binary fuzzy contrast method to determine the weight coefficient for each factor.

Binary fuzzy contrast method quantify the degree of importance under the principle of complementarity, and construct a binary contrast matrix$A$, in this matrix A, a_{ij} stands for the relatively

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importance of two factors A_i and A_j, a_{ij} can only be 0, 0.5 or 1 and $a_{ij} + a_{ji} = 1$ (complementary principle). If A_i seems more importance than A_j, thus $a_{ij} = 1, a_{ji} = 0$, on the contrary, $a_{ij} = 0, a_{ji} = 1$, if they are equally important, $a_{ij} = a_{ji} = 0.5$, here, $i = 1,2 \cdots n, j = 1,2 \cdots n$, ($n$ is the number of factors). It is clear that when $i = j$, $a_{ij} = a_{ji} = 0.5$. The binary contrast matrix A is as follows:

$$A = \begin{bmatrix} a_{11} & \cdots & a_{1n} \\ \vdots & a_{ij} & \vdots \\ a_{n1} & \cdots & a_{nn} \end{bmatrix}, (i = 1,2,3 \cdots n, j = 1,2,3 \cdots n) \quad (8)$$

In order to get the weight coefficient of each factor, first, we calculate the row sums and get the initial weighted eigenvector W_0. See formula (9)：

$$W_0 = [w_1 \quad \cdots \quad w_n]^T = [\sum_{j=1}^{n} a_{1j} \quad \cdots \quad \sum_{j=1}^{n} a_{nj}]^T \quad (9)$$

Normalize W_0 to get the weight coefficient vector $\overline{W}$ where $\overline{w_i}$ stands for the weight coefficient for factor i.The normalization process shows in formula (10).

$$\overline{W} = [\overline{w_1} \quad \cdots \quad \overline{w_n}]^T = \left[\frac{w_1}{\sum_{i=1}^{n} w_i} \quad \cdots \quad \frac{w_n}{\sum_{i=1}^{n} w_i}\right]^T \quad (10).$$

Finally, the comprehensive utility function should be as follows:

$$F = \overline{M} \cdot \overline{W}^T \quad (11)$$

Comparing the comprehensive utility value of each rapid transit mode, one can easily chose the highest utility value and, that would be the most appropriate mode for the urban transportation corridor.

4 Case study

4.1 Backgrounds

Zhenjiang New District (i.e. China National Zhenjiang Economic and Technological Development Zone) is situated in the eastern suburb of Zhenjiang. It administers Dingmao Sub-District, Dagang Sub-District and three towns (Dinggang Town, Dalu Town, Yaoqiao Town) under its jurisdiction with the total area of 218.9 km^2 and a population of 217,000. The distance between the central area of Dagang Sub-District and Dingmao Sub-District is about 16km along Jingang Avenue, which is the main arterial, and the most direct path between the two separated areas.

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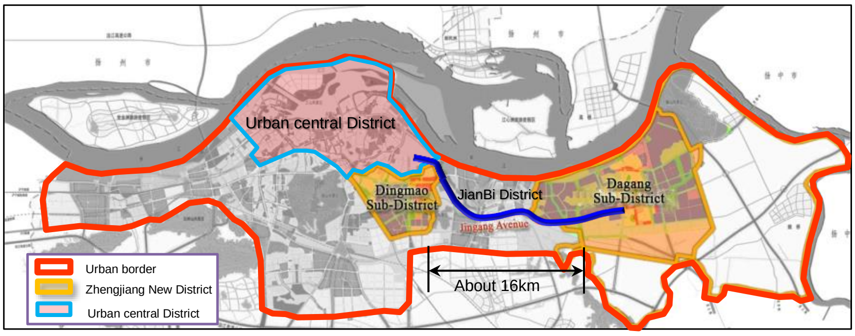

Fig.ure 5. Location of Zhenjiang New District and Jingang Ave.

Since upgraded to a state-level economic and technological development zone in 2010, Zhenjiang New District has seen rapid social economic growth, with a regional GDP totaled 55 billion ￥ in 2015, and an average annual GDP growth rate of over 10%. As a state-level Economic and Technological Development zone, Zhenjiang New District features high-tech industries. It aims at developing a regional industry pattern dominated by high and new technology, supported by advanced manufacturing and modern service industry. Since its establishment, the people and goods exchange between the two sub-districts and between Zhenjiang New District and the main city has kept on growing. The increasing traffic needs calls for an augment of the existing roadway system, and a rapid transit system is needed to supplement its capacity.

4.2 Current situation and development analysis

4.2.1 Existing rRoadway system

As shows in Fig.6, there are four east-west roads directly access from Dagang Sub-District to Dingmao Sub-District, including: Jingang Avenue, which is an eight-lane major arterial with four lanes (including one planned bus-exclusive lane) running in each direction; the four-lane Yuehe street; the six-lane Linjiang Road; and the six-lane East Dantu Road.

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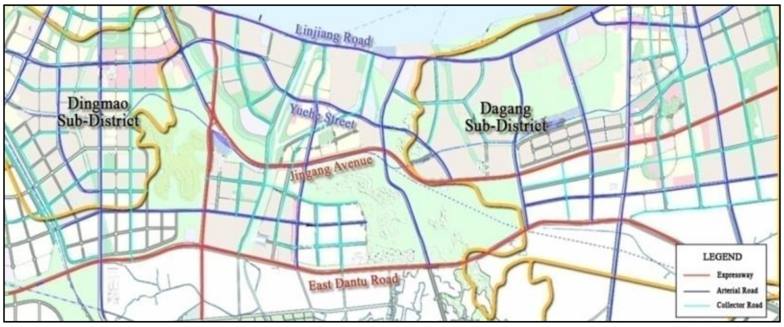

Fig.ure 6. Transportation System Plan for 2020 in Zhenjiang New District

Jingang Ave. currently has a right-of-way of 54m, the typical cross-section (Fig. 7) is 8 lane, and two side lane on each direction. The minimum radius is 400m and the maximum slope is 3.77%.

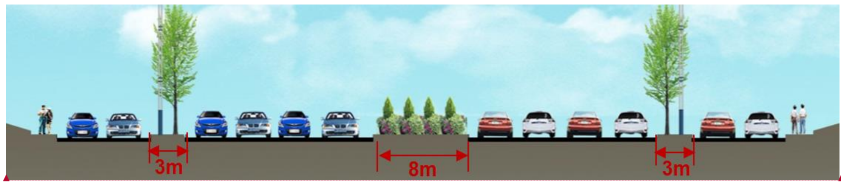

Figure Fig. 7. Cross-Section of Jingang Avenue

The traffic volume on Jingang Ave is expect to grow with the economic and social development of the study area, as this road will takes the most direct traffic volume from east to west.

4.2.3 Public Transportation

There are currently 7 public transportation lines between Dingmao and Dagang, among which 6 are along Jingang Ave, indicating high redundancy rate. In "Public transportation plan in Zhenjing rural and urban areas (2011-2020)", Jingang Avenue is denoted as the class I public transportation corridor connecting Zhenjiang New District. The plan also recommend building bus exclusive lanes and major transit lanes along this road.

Zhenjiang has no rail transportation and no rail transit will be provided before 2020. Tail transit line 3 is planned in the "Urban master planning of Zhenjiang（2002-2020）（2015revise）" for the year 2050. This line will connect the central urban and Zhenjiang New District.

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4.3 Demand Analysis of Rapid Transit Mode

4.3.1 Ridership Forecast

According to the “Public transportation plan in Zhenjing rural and urban areas (2011-2020)”, the AM peak hour ridership and origin-destination traffic volume among each traffic analysis zone in 2020 is shown as Fig.8.

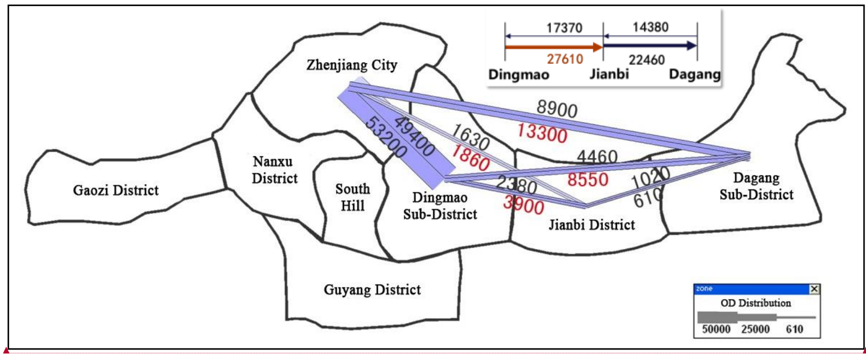

Fig.~~ure~~ 8. Passenger distribution of Zhengjiang city in 2020 AM peak hour

The ridership between urban core and Dagang is expected to reach 13,300, with the peak volume of 27,610 in the segment of Dingmao to Jianbi (west to east). As Jingang Ave has reserved the space for one bus exclusive lane on each direction, the study will consider its capacity as 6 lanes, double direction plus 2 bus exclusive lanes.

According to the capacity calculation method in “Highway Capacity Manual 2000” the capacity for 3 lane in one direction is about 5,260pcu/h. Suppose each car takes 1.5 people, the one-directional ridership capacity of Jingang Avenue is 7,890 /h. The capacity for bus exclusive lane is calculated by bus headways. Given the headway of 20s (considering the time for boarding at bus stops), one-directional bus capacity is about 180 per hour. If each bus takes 25 people, the ridership capacity will be 4,500 per hour.

Given that Jingang Avenue has a passenger capacity of 12,390 per hour and reaches 80%-90% of its maximum capacity in 2020, if the other east-to-west roads take 40% of the total ridership, there will still be an unmet passenger demand of about 5,000-7,000 per hour. The gap will grow wider with the

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time and is likely to reach 10,000-15,000 per hour.

Therefore, a medium-level rapid transportation will not only meet the ridership needs in the short term (2020), but also could serve as a transition phase to the planned rail line in 2050.

4.3.2 The need for Urban Development

Zhenjiang new district is the national economic development district, the development of general aviation, new materials, new energy and other strategic emerging industries. It is also paying attention to urban environment and ecological system construction, aiming at building itself into a demonstration zone of Zhenjiang green ecological district.

Therefore, on the premise of meeting the demand of passenger transport, rapid transit systems should be in line with Zhenjiang new district's development orientation, for example, low carbon environmental protection of rapid transit system, and interact with the emerging industry, thus promote the new development of new materials, new energy industry.

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4.3.3 Factors to consider

(1) Capacity

The analysis of development of Zhenjiang New District and the ridership forecast suggests a capacity gap of 5,000-15,000ridership/h. This new system will be a supplement of the roadway corridor between Dingmao and Dagang so it should have enough capacity.

(2) Level of Service

Being an alternative way to building roadways, the system should have an average speed comparable to the D-level freeway speed, which is approximately 30km/h. Meanwhile, as Zhenjiang has no plan to build large-capacity, high-speed rail system before 2050, the system is expected to provide convenient and guaranteed service, as a substitute for rail system.

(3) Unit construction cost

As an indicator of investment, average construction cost is crucial for the decision making on transportation modes. Instead of spending the same funds on a more extensive system, it may be preferred to spend less on a system serving the same corridor.

(4) Unit energy consumption

Under the same transport capacity, operating conditions, service level and construction cost, policy makers are usually more willing to choose clean energy, low energy consumption of the rapid transit system, in order to reduce the overall cost and operating managers' economic burden.

(5) Supporting emerging industries

New transportation mode should be able to support the development of emerging industries in Zhenjiang New District. It should meet the development goal of this district, protect the environment, and interact with the emerging industry, thus promote the new development of new materials, new energy industry.

4.3.4 Initial Rapid transit mode selection

Considering the district's development goal and ridership demand, Jingang Avenue needs a rapid transportation system to supplement its capacity. The rapid transit system to be selected should have a capacity of 5,000-15,000ridership/h, provide high level of service, low carbon, environmental friendly, and have the potential to promote the new material and new energy industry. Preliminary study indicates three options: BRT, Modern tram, and PRT.

In term of the above-mentioned factors, a subjective comparison is made in Table1.

Table 1. Subjective comparison of selected rapid transit

Comparison Factors	BRT	Modern tram	PRT
Capacity	◒	●	◒
Average travel speed	◒	◒	◒
construction costs	◒	◒	●
energy consumption	●	◒	●
support of Emerging industries	◒	●	●

Notes: ●Excellent ◒Average ○Poor

Form the perspective of qualitative judgment, PRT seems more suitable for this transportation corridor, but we need more quantitative analysis to select the most appropriate one for this corridor as a reference for decision making.

5 Results and discussion

5.1 Weight coefficient for each factor

We can get one weight coefficient result $\overline{W}$ with one binary fuzzy contrast processing, In order to ensure the rationality of the weight coefficient of the rapid transit mode selection factors, we invited eight experts who will enroll in the decision making and transportation planning, separately took binary fuzzy contrast processing and got eight results, then, take the arithmetic average of each weight coefficient as the final result, shows in Table 2.

Table 2. Result of weight coefficient

Utility Indicator	Capacity	Level of Service	Unit Construction Cost	Unit Energy Consumption	Supporting emerging industries
Weight	0.21	0.26	0.23	0.17	0.13

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The weight coefficient result shows that, Level of Service is the most important factor when considering a transit mode, coincide with the demand of rapid connection between Zhenjiang new district and urban central district; Unit Construction Cost lists in 2nd place and capacity in 3rd, those make sense since decision makers should balance the finance income and construction investment, and consider whether the investment can meet the total traffic demand. Supporting emerging industries ranks last.

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5.2 Technical Comparison

Table 3 shows the technical parameters of the above-mentioned factors of BRT, Modern tram and PRT. Characteristics of these three modes are provided by manufacturers in recent years across the world.

Table 3. Characteristics of typical BRT, Modern tram and PRT

Comparison Factors	BRT	Modern tram	PRT
Max Capacity (pphpd)	6,000-12,000	5,000-15,000	7,200-13,000
Average travel speed (km/h)	18-30	24-40	37-65
construction costs($million /km)	6-12	10-15	5-8.5
energy consumption(kWh/veh.km)	3.5	3.5	0.25

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Here, Capacity of transit system depends on the frequency of service (headway) and vehicle capacity. The more passengers on one vehicle, the shorter the headway is, the bigger the capacity. "Standard Classification of Urban Public Transportation" states that BRT services using standard buses (length 13-24m carrying 110-200passengers per vehicle) operating with headways of 1 min, can carry

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about 6,000-12,000 in the peak hour / direction. For Modern trams, capacity is depended on the number of its compartment, or its length. Each compartment contains passengers about 170-500, the longest tram is about 54m, and the shortest headway is about 2min. Generally speaking, Modern trams can reach a capacity of 5,000-15,000ridership/h. PRT Consulting provided some data about its operation and shows that the headway can be reduced to less than 5s; the capacity can reach 7,200-13,000 accordingly.

Considering the energy consumption, BRT has less advantages as most of BRT vehicles burn fuel, although there are some application of mixed energy or battery, it’s still hard to be applied on a large scale. So the electric or battery driven Modern tram or PRT will serve better for the solar power industry of Zhenjiang New District. Meanwhile, all the three modes welcome new material, like fiber reinforced plastic for their vehicles and strong rubber for the wheels.

Substitute technical parameters provided above into the initial Index matrix M:

$$M=\begin{bmatrix} 6{,}000-12{,}000 & 5{,}000-15{,}000 & 7{,}200-13{,}000 \\ 18-30 & 24-40 & 37-65 \\ 6-12 & 10-15 & 5-8.5 \\ 3.5 & 3.5 & 0.25 \\ 0.5 & 1 & 1 \end{bmatrix} \qquad (12)$$

In this matrix, three columns respectively stands for BRT, Modern tram and PRT, five rows respectively stands for five decision making factors, and the element of the matrix basically not a fixed value, but a range. Consider the value of emerging industries Supporting factor, here we set the value for BRT is 0.5 (partly support), and the others are 1 (well support).

5.3 Comprehensive utility results

In the above initial Index matrix M, considering the cost and energy consumption are inversely proportional to the discretion of the utility, in another word, the more it cost, or the more energy it uses, the lower utility it will get. Therefore, the utility value of cost and energy consumption index is the inverse function in the above initial Index matrix M.

Under the processes of nondimensionalize and calculation using Eq.(7) to Eq.(10),we got the Comprehensive utility results, for a more intuitive expression of the comprehensive utility level, using the hundred-mark system to display calculation results.

Table 4. Results of Comprehensive utility

Mode	Comprehensive utility (Min)	Comprehensive utility (Max)	Comprehensive utility(Ave)
BRT	26.8	28.4	27.6
Modern tram	32.8	35.5	34.1
PRT	57.6	58.6	58.1

Table 4 shows that PRT has the largest average comprehensive utility value (58.1), while BRT has the smallest value (27.6), and Modern tram is in the middle (34.1). Judging from the analysis results, PRT can better meet the need of rapid transportation in the study area, and can be considered as the first choice in the near future.

5.4 Recommendation

Based on the given requirements of Jingang Avenue and the judgement of technical parameters of three rapid transportation modes, PRT system seem to be more suitable for its comparative advantage. Furthermore, comprehensive utility matrix was built for the three modes based on their capacity, level of service, unit construction cost, unit energy consumption and their support to emerging industries. Results show that PRT gets the highest comprehensive utility value compared to the other two modes, which confirmed the judgment of quantitative analysis. Considering the above five factors, PRT is the first choice for the rapid transit mode selection in Zhenjiang New District.

6 Conclusions

This paper provides a quantitative method to evaluate the comprehensive utility of different rapid transit modes, which involves nondimensionalize utility matrix and binary fuzzy contrast method to determine weight coefficient. Accordance with the principle of comprehensive utility maximization, the quantitative methods proposed in this study can be used as a decision-making reference for selecting rapid transit mode within urban transportation corridor.

As our case study is limited within five factors: transport capacity, level of service (or average travel speed), cost of construction, energy consumption and support of emerging industries, more

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considerations should be made on the actual transit mode selection, such as construction condition, environment, and its integration with other transportation modes. In further study, the quantitative analysis method proposed in this paper can be used as one of the mode selection criteria, just add more corresponding consideration factors in the selection index, and the quantitative analysis could also work.

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