Study on the Selection of Middle Urban Mass Rapid Transit System and Adaptability Analysis

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Abstract

With the increase of traffic demand, the concept of coordinated development of multiple modes of transportation dominated by public transportation has become a consensus. Many large cities are actively developing three-dimensional urban rail transit and constructing a public transport network with urban rail transit as the backbone. Due to its small volume and flexible route selection, medium volume traffic has been favored by many cities. In this paper, a comprehensive decision-making model of the system is established by DEA data envelopment analysis method, based on the research and analysis of various middle mass rapid transit system. Taking Yongxiu County of Jiangxi province as a case, the adaptability of Bus Rapid Transit (BRT), Autonomous Rail Rapid Transit (ART) and Rail Transit were evaluated and ranked. In the meantime, this paper studied the selection of the system of mass transit system and its adaptability to Yongxiu County.

Key words: Middle urban mass rapid transit system, Standard selection, Adaptability

1 Introduction

Due to the rapid growth of car ownership and the lag in the construction of road facilities in recent years, the vulnerability of urban transport network has become a hot and difficult problem in the current research on road network [1]. By virtue of its own advantages and development potential, the middle urban mass rapid transit system has received more favor and attention, and has gradually become a powerful supplement to the mass transportation system of ground and rail. Middle urban mass rapid transit system mainly includes Rail Transit, Bus Rapid Transit (BRT） and Autonomous Rail Rapid Transit (ART), which is quite recent. The classification of urban public transport system types is shown in Figure 1.

Most of the domestic and foreign metropolises built a multi-level rail transit network and operated well by monorail, APM and other low traffic volume system, These low and medium volume systems are diversified, flexible in route selection and small in size, complementing urban railways and subways [2]. The related work can be appied in various new emerging scenarios [3-7].

Famous scholars at home and abroad have studied the MRT system. Jingyan Shen. Based on the basic concept of “traffic class and support guiding system”, discussing various systems and putting forward the evaluation system and principles of “function, environment, safety and economy” for the selection of various systems [8]. Almasi M H, Oh Y, Sadollah A, et al. found an optimum set of transit routes that corresponds to chosen tradeoffs between user cost, operator cost and, notably, unsatisfied demand cost [9]. Jinhui Zhang studied the selection of urban rail transit

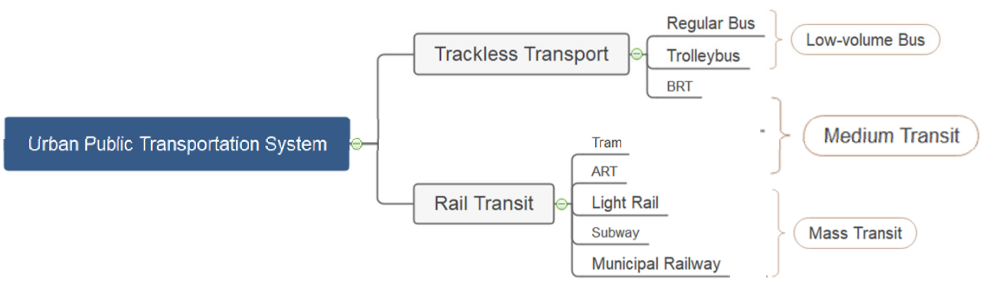

Figure 1. Types of urban public transport systems

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vehicle system, and used Analytic Hierarchy Process (AHP) and Fuzzy Comprehensive Evaluation to comprehensively evaluate vehicle system [10]. According to the hierarchy of urban rail transit selection and the goals and contents of the selection work in the line network planning stage, a three-level selection theoretical system of “rail transit mode-system standard-vehicle standard” is proposed by Lingyang Kong, and also proposed an optimization model for urban rail transit selection in terms of functional performance, application scope and technical characteristics of urban rail transit [11]. Ying Xu established the standard decision model of medium and low volume urban rail transit system by using the AHP -Grey Relational Degree Analysis Method, and took the system standard selection of Yuquan line of Beijing rail transit as an example to verify the effectiveness of the method [12].

The efficiency evaluation theory is mainly used to establish the comprehensive evaluation model of public transportation lines for the selection of middle urban mass rapid transit system. It was first proposed by Farrell in 1957, which constitutes the basic idea of Data Envelopment Analysis theory (DEA) [13]. Lovell, R. Färe and others discussed the enterprise efficiency evaluation proposed by Farrell in detail [14-16]. DEA is a tool for evaluating the relative effectiveness of comparable decision-making units. Besides, the similar evaluation research has been studied in different fields [17-21].

The efficiency of DEA depends on the distance between the evaluated Decision Making Unit (DMU) and the optimal DMU, and has nothing to do with the DMU with poor performance [22].

By means of input and output, various evaluation indexes for relative effectiveness of DMU of the same decision type are determined and calculated respectively [23]. Directly analyze how to determine the direction and degree of improvement of non-DEA effective corporate decision-making management units based on the “projection principle”, so as to provide corporate managers and personnel with important corporate management decision-making information.

Efficiency was originally defined as a concept applied to physics, later, the concept of efficiency has been extended a lot in economics, and many fields of economics have applied such concepts to systematically evaluate efficiency. This paper introduces about the concept of efficiency in traditional economics field of public transportation, the MRT system, think the MRT system provided by the bus lines and public transport infrastructure is mainly put in, the investment of the facilities in the route planning, operation and services as the main output, the effect of unit of the MRT system produced by the resources of the public transportation route planning, operation, service, this paper further defined as the effect of the MRT system efficiency of regular bus.

Based on the research and analysis of various middle urban mass rapid transit system, this paper establishes a comprehensive decision-making model for middle urban mass rapid transit system by means of DEA data envelopment analysis. Taking Yongxiu County in Jiangxi Province as a case, the appraisal and sorting of the adaptability of the three system systems of BRT, ART and tram system are carried out, and the selection of the system of mass transit system and its adaptability to Yongxiu County are studied.

2 Analysis of Middle Urban Mass Rapid Transit System

Medium-capacity buses mainly include low- and medium-speed trams, Bus Rapid Transit (BRT), and the newly emerged Autonomous Rail Rapid Transit (ART), etc.

Bus Rapid Transit (BRT) is a new type of transportation system with operating speed and passenger transport capacity between rail transit and conventional buses, which can achieve high capacity and high efficiency transportation capacities through its exclusive bus corridor, and use the transportation strategy of “transit priority” to increase the operation speed.

Trams are light rail vehicles that are powered by electricity and carry about 6,000 passengers per hour. Compared with traditional trams, modern trams can be designed to run by various ways of right of way [23]. The passenger capacity of modern trams is shown in the Table 1.

Table 1. Modern tram single train passenger capacity

Passenger comfort	Train-frame		
	Three modules	Three modules	Three modules
seat	40	56	70
Comfortable (seating + standing 4 people /m^2)	180	254	360
Normal (seating + standing 6 /m^2)	220	310	430
Maximum (seating + standing 8 people /m^2)	280	400	550
Maximum peak load (1.15 times of passengers per 8 people /m^2)	320	460	630

Autonomous Rail Rapid Transit (ART) is a new type of medium quantity transport system [24]. ART adopts the flexible grouping mode of high-speed rail, which can adjust the number of passengers according to the change of passenger flow, and can carry different numbers of passengers according to the different grouping, which can make up for the defects of other modes of transport with small volume [25].

Electric drive technology is regarded as one of the most promising technologies to solve the fossil fuel energy crisis and environmental pollution worldwide [26]. When the city chooses the MRT system, it will comprehensively consider the transportation capacity, technology, economy, environmental protection and other dimensions, and choose the best one.

In terms of technical characteristics, BRT and ART are driven by electric power. From the point of view of aesthetics and comfort, ART and modern tram have a better contribution to the construction of urban culture and can improve the ride experience. Compared with tram, ART has lower upfront costs and operating costs.

From a capacity point of view, the BRT chose a fixed form and could not be marshalled and reconnected. However, its transport capacity is basically the same as that of the tram.

The safety of traffic is also attracting more and more attention. ART express train is equipped with PIS, CCTV audio information system and GPS positioning system [27] on the basis of multi-axis steering system to follow and control the track and ensure the running on the preset track.

3 Standard Selection Evaluation Method for Middle Urban Mass Rapid Transit System

In essence, the comprehensive evaluation system of medium-volume rapid transit line is a system of comprehensive analysis and evaluation with multiple indicators. This paper mainly establishes a comprehensive evaluation model by using Data Envelopment Analysis (DEA) method, and select the appropriate Middle Urban Mass Rapid Transit System according to the characteristics and needs of different cities.

3.1 Selection of Evaluation Indexes

The design of the evaluation index system of urban mass transit system should have the following characteristics:

(1) The indexes of urban bus line planning and evaluation should conform to the national standard of urban bus;

(2) To accurately and reasonably evaluate the level of urban bus line service planning and the effect of actual urban bus line service;

(3) Under the prerequisite of not directly affecting its accuracy, the design of the index system should be as simple as possible.

After researching, the indicators for evaluating the rationality of bus line transfer space planning connectivity mainly include the following four items: line length, number of stations, average station distance, average speed of station transportation and peak load rate. Based on the above understanding of the evaluation index content of service level of medium volume rapid transit system, this paper studies and constructs a set of relatively conventional evaluation index system of bus line service level, as shown in Figure 2.

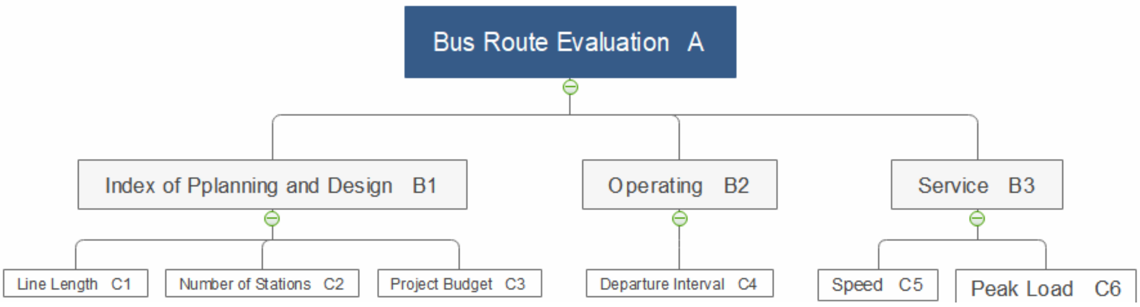


Figure 2. Evaluation index system of bus line service level

3.2 Comprehensive Evaluation Model of Middle Urban Mass Rapid Transit System Lines

Assuming that there are more than n evaluation bus lines input and evaluated in the city, each input evaluation bus line should have more than m kinds of improved input and output evaluation index and a s type of improved output input evaluation index, which represents the q-th output input evaluation index of j-th input evaluation bus line, It refers to the r-th improved output input evaluation index (q = 1,2,n; r = 1,2, s) of the j-th input evaluation and evaluation of bus lines, then the objective index of each input and output evaluation of the j-th input evaluation is determined by the number of the following indicators for evaluating the optimal evaluation value of the bus line after comprehensive mathematical planning:

$$\max h_j = \frac{\sum_{r=1}^{s} u_r y_{rj}}{\sum_{q=1}^{m} v_q x_{qj}} \tag{1}$$

$$\text{s.t.} \quad \begin{cases} \sum_{r=1}^{s} u_r y_{rj} - \sum_{q=1}^{m} v_q x_{qj}, (j=1,2,...,n) \\ u_r \geq 0, r=1,2,3,...,s \\ u_q \geq 0, q=1,2,3,...,m \end{cases} \tag{2}$$

Where: v_q is the weight coefficient of the input index q; u_r Is the weight coefficient of output index r. Through the dual transformation of C^2 , can be obtained

$$\min = V_D \tag{3}$$

$$\text{s.t.} \quad \begin{cases} \sum_{j}^{n} x_j \lambda_j + S^- = \theta x_j \\ \sum_{j}^{n} y_j \lambda_j + S^+ = y_j \\ \lambda_j \geq 0, (j=1,2,...,n) \\ S^- \geq 0, S^+ \geq 0 \end{cases} \tag{4}$$

Where: S^- is the relaxation variable and S^+ is the residual variable.

If the optimal value $V_D = 1$, then the j-th bus line is effective with weak DEA; If, under the above conditions, each of its optimal solutions has $S^+ = 0$, $S^- = 0$, then the j-th bus line is DEA effective, and the optimal value is the comprehensive evaluation index of the JTH bus line.

In practical problems, often have more efficiency of decision making units can take to the largest value of 1, It is generally impossible to distinguish the pros and cons of these decision-making units with only V_D, thus introducing against type cross efficiency model for decision making units in order to the method when determining weights as far as possible to maximize their efficiency, at the same time as far as possible minimize other decision-making unit efficiency, realize the “self assessment” and “he review”.

The cross efficiency evaluation matrix is

$$E = \begin{vmatrix} E_{11} & E_{12} & \cdots & E_{1n} \\ E_{21} & E_{22} & \cdots & E_{2n} \\ \vdots & \vdots & \cdots & E_{11} \\ E_{n1} & E_{n2} & \cdots & E_{22} \end{vmatrix} \tag{5}$$

The matrix represents the evaluation value of the i-th DMU for the j-th DMU, that is, the cross-efficiency evaluation value, When i=j, E_{ij} is equal to the evaluation result of the C^2R model, and the average value in the j-th column represents the comprehensive evaluation result of the decision-making unit DMU_j.

4 A Case Study on the Standard System of Middle Urban Mass Rapid Transit System in Yongxiu County of Jiangxi Province

4.1 Overview of Yongxiu County

Yong xiu county is located in Jiangxi provincial development strategy lake with a shaft axis (Jingjiu development prosperous nine section) important intersection, which is an important hub and strategic transportation pivot for the construction of Changzhou-Kowloon intercity expressway corridor.

Under the background of the rapid development of backbone cities, Yongxiu County needs to study and construct a multi-level backbone public transportation system structure to make up for the lack of existing public transportation service system structure. In addition, the construction of Mass Rapid Transit system (MRT) can also help realize the synergies of “industry-driven projects and project-driven industries”.

4.2 Standard Selection Scheme of Medium Volume MRT System

Considering the urban population and Gross Domestic Product (GDP) size of Yongxiu County, the basic conditions for the application of medium-low speed light rail development in 2003 are corresponding. Light rail and medium-low speed magnetic levitation are not suitable for the actual development situation of Yongxiu County. However, the cable rail system of medium and low speed light rail magnetic levitation is too expensive and the technology is not mature enough at present, so the cable rail system is not considered for the time being.

Therefore, there are three alternative standard schemes for the medium volume rapid transit system, namely BRT, ART and tram.

4.3 Determine Evaluation Indexes

4.3.1 Selection of Input Indicators

The input index mainly refers to the input of bus operation service enterprises and providers, namely, the human resources and resources that bus operation enterprises need to invest in bus service operation. For example, the number of vehicles in bus operation, the running length of the line and the average running station distance, etc. These indicators of input data can be directly to the survey data to calculate the local bus company and access.

4.3.2 Selection of Output Indicators

The revenue and output of public transport services are different in nature, including passenger volume, ticket sales, service satisfaction, ride comfort and other quality outputs. Since the DEA evaluation index model in this paper requires that the number of each evaluation index should not exceed that of each unit in bus service decision-making, this paper mainly selects 6 evaluation models with large weight as the indexes. The final input and output indicators are shown in Table 2.

4.4 DEA model Calculation Process and Results

4.4.1 Input and Output Index Data

Table 2. Input and output indicators and meanings

Satisfaction Evaluation	The Index Type	Indicators	Meaning
bus line service satisfaction evaluation index U	input indicator U1	line length U11	total length of bus lines (km)
		number of sites U12	the number of stops on the bus route
		departure interval U13	the time between two bus shifts before and after leaving the departure station (min)
		project estimate U14	engineering Investment and Cost calculated at the preliminary design stage of construction (100 million YUAN)
	output indicator U2	delivery speed U21	speed at which public transport vehicles carry passengers (km/h)
		peak load factor U22	the average full load of passengers carried on the line during peak passenger hours

Table 3. Statistical results of input and output indicators of DEA model

Standard	Input Indicators				Output Indicators	
	Line length (km)	The Number of Sites	Departure Interval (min)	Estimated Project Cost ($100 million)	Transport Speed (km/h)	Peak Load Factor
ART1	5	4	20	2	25	0.946
ART2	14	14	15	5.6	25	0.914
ART3	20	19	12	8	25	0.977
ART4	6.6	5	10	2.64	25	0.817
BRT1	5	4	10	3	30	0.869
BRT2	20	19	5	12	30	0.898
BRT3	17.5	14	6	10.5	30	0.826
BRT4	6.6	5	10	3.96	30	0.902
Tram1	5	8	15	6.5	35	0.848
Tram2	20	19	7	26	35	0.834
Tram3	9	15	10	11.7	35	0.805
Tram4	6.6	5	10	8.58	35	0.733

4.4.2 Adjustment and Analysis of Results

According to the C^2R model, the relative efficiency results of the MRT lines in each medium volume system are calculated as shown in Table 4. Ass shown above the optimal solutions of ART1, ART4, BRT1, BRT2, BRT3, BRT4, tram 1 and tram4 are theta 1. The optimal solutions of all the relaxation variables in these decision units are all equal to 0. Thus we can accurately determine the bus lines reached the DEA effective, namely under the condition of the line input costs remain the same line production cost to achieve the optimization, bus and enterprise operation and provide bus service utmost to allow passengers to feel the quality of service the optimal, other several bus lines of the optimal solution of theta are less than 1, The DEA is not effective.

For the effective bus lines, can simply by looking for DEA is relatively effective running the plane to adapt and improve its value indicators, projection value generally refers to the effective bus lines are in a state of best service operation projection value of input and output two indexes corresponding projection values, adjust the results as shown in Table 5.

Use against cross link efficiency evaluation system model analysis and calculation of the average relative efficiency of various types of bus lines. Through the analysis of calculating the average efficiency of each column in the matrix can be various types of bus lines to the relative values of efficiency and the quality of the fit and unfit quality value sorting, calculation results and sorting as shown in Figure 3.

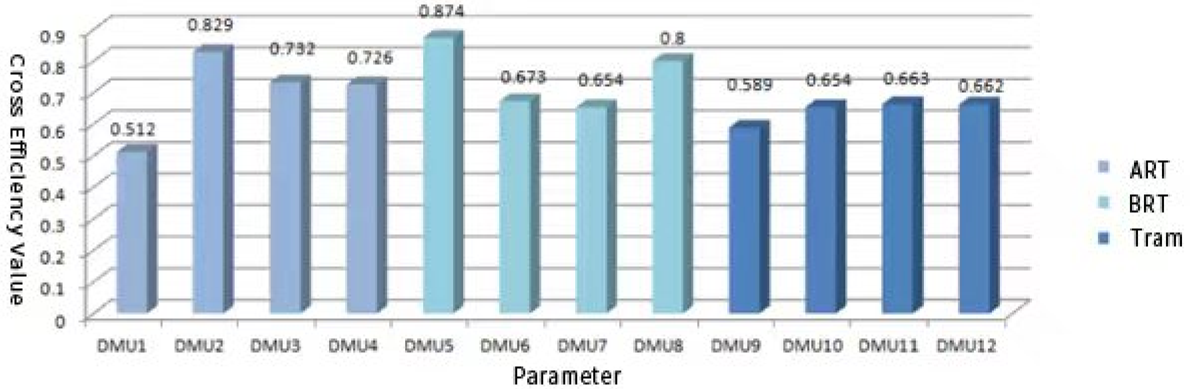
Among them, BRT1 has the highest comprehensive evaluation value among all the lines of MRT system. The average comprehensive evaluation value of each rail line is the highest for each MRT system, which indicates that the output of wisdom rail is maximized at the current input level after integrating the information data of each MRT system into the model calculation.

Table 4. Evaluation results of bus routes based on the C2R model

		Input Indicator Relaxation Variable S -				Output Indicator Slack variable S +	
		Line Length (km)	The Number of Sites	Departure Interval (min)	Estimated Project Cost ($100 million)	Transport Speed (km/h)	Peak Load Factor
DMU i	theta	S_1	S_2	S_3	S_4	S+1	S+2
ART1	1	0.0	0.0	0.0	0.0	0.0	0.0
ART2	0.7	3.2	4.2	0.0	0.0	6.5	0.0
ART3	0.8	5.3	5.6	0.0	0.0	8.4	0.0
ART4	1	0.00	0.00	0.00	0.00	0.00	0.00
BRT1	1	0.00	0.00	0.00	0.00	0.00	0.00
BRT2	1	0.00	0.00	0.00	0.00	0.00	0.00
BRT3	1	0.00	0.00	0.00	0.00	0.00	0.00
BRT4	1	0.00	0.00	0.00	0.00	0.00	0.00
Tram1	1	0.00	0.00	0.00	0.00	0.00	0.00
Tram2	0.97	0.00	0.30	0.00	12.53	0.00	0.14
Tram3	0.96	0.00	7.28	0.00	2.57	0.00	0.00
Tram4	1	0.00	0.00	0.00	0.00	0.00	0.00

Table 5. Result of index adjustment of decision making unit with invalid DEA

Decision Units	Bus Routes	Before and After Adjustment	Input indicators				Output indicators	
			Line Length (km)	The Number of Sites	Departure Interval (min)	Estimated Project Cost ($100 million)	Transport Speed (km/h)	Peak Load Factor
DMU2	ART2	before	14	14	15	5.6	25	0.91
		after	6.31	5.26	10.14	3.79	31.48	0.91
DMU3	ART3	before	20	19	12	8	25	0.98
		after	10.53	9.42	9.48	6.32	33.4	0.98
DMU10	Tram2	before	20	19	7	26	35	0.83
		after	19.44	18.17	6.8	12.74	35	0.97
DMU11	Tram3	before	9	15	10	11.7	35	0.805
		after	8.68	7.19	9.65	8.72	35	0.81



Fugure 3. Evaluation results and ranking of the cross efficiency model

But out of its four tracks, Track 1 ranked last. Therefore, by removing one input index one by one and then recalculating, the index that has great influence on the structure can be obtained.

After removing one input or output index one by one and then recalculating, it is concluded that the departure interval has great influence on the evaluation result of the circuit. In the previous ranking of cross efficiency values, the starting interval of the two low-ranked wisdom rail lines was reduced and then recalculated. The result is as Table 6:

The adversarial cross efficiency evaluation model is used to calculate the relative efficiency of each bus line. By calculating the average value of each column in the matrix, the average efficiency value of each bus line can be obtained for sorting of advantages and disadvantages. The calculation results and sorting situation are shown in Figure 4.

From the adjusted results, it can be concluded that the efficiency value ranking of ART1 has been

Table 6. Adjustment results of invalid decision unit indexes of new DEA

Decision making units		DMU2		DMU3		DMU4		DMU8		DMU10		DMU11	
Bus routes		Think tank track 2		Think tank track 3		Think tank track 4		BRT4		Tram 2		Tram 3	
Before and After Adjustment		before	after	before	after	before	after	before	after	before	after	before	after
Input Indicators	Line Length (km)	14	5.79	20	8.92	6.6	5.63	6.6	5.63	20	19.4	9	8.49
	The Number of Sites	14	4.8	19	7.87	5	4.46	5	4.46	19	18.17	15	7.11
	Departure Interval (min)	15	6.81	12	6.82	7	8.92	10	8.92	7	6.79	10	9.44
	Estimated Project Cost ($100 million)	5.6	2.54	8	4.55	2.64	3.53	3.96	3.53	26	11.3	11.7	3.82
Output Indicators	Transport Speed (km/h)	25	25	25	27.36	25	30	30	30	35	35	35	35
	Peak Load Factor	0.91	0.93	0.98	0.98	0.817	0.96	0.902	0.96	0.83	1.11	0.805	1.3

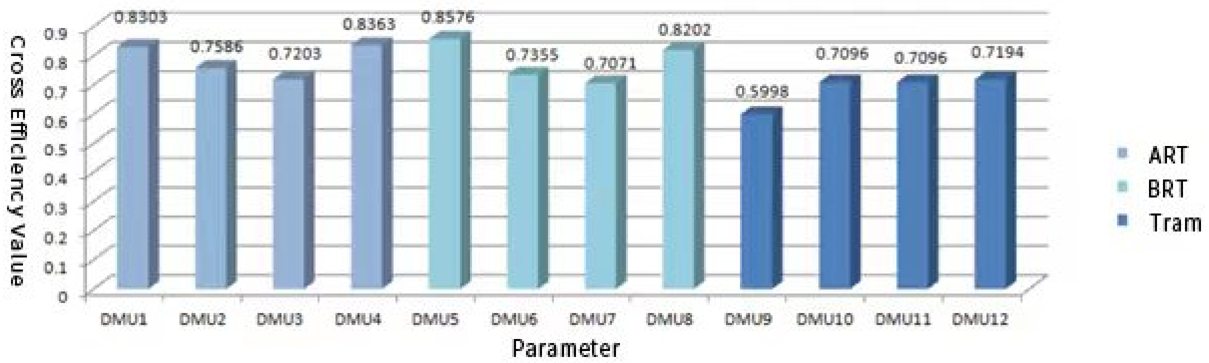


Figure 4. Evaluation results and ranking of the crossover efficiency model

significantly improved after the starting interval of ART1, which ranks lower in the previous results, has been reduced. It can be concluded that the interval of departure has a great influence on efficiency.

MRT operators want to provide the required volume with a small number of high-capacity bus units, but passengers want shorter intervals and faster service. At the same time, due to the flexible grouping mode of high-speed rail, The Intelligent rail train can also adjust the capacity according to the changes of passenger flow. When the section flow is small, it can use fewer cars but maintain a shorter departure interval to meet the needs of passengers. Therefore, it is of great reference value to optimize and adjust the operation mode of public transportation through model calculation.

5 Conclusion

It is an important direction to develop urban transportation at home and abroad. Current construction technology is relatively mature and is suitable for permanent fix counties of three kinds of traffic in the city MRT system (BRT, ART and modern tram) general situation of the development, application and technical characteristics are summarized, the research analyzed the main factors affecting system choice, using the data envelopment analysis DEA, the absorption of expert experience and knowledge at the same time reflects the importance of each index itself, and starting from the objective data, to quantify the system trend of comparative analysis, to reduce the impact of human factors, calculated using alternative three system adaptability of sorting, For Yongxiu county to choose a relatively suitable standard for development.

The choice of urban rail transit system standard is a complex system engineering, with many influencing factors. This paper is only a preliminary study on this problem, and further study is needed to optimize the established evaluation index system. In the study on the standard selection of the mid-volume rapid transit system in Yongxiu County, the peak period is taken as the research target. In the further study in the future, the travel schedule can be more detailed according to the traffic demand of a specific time period of a route, and the marshaling method can be determined.

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Reference

[1] W. W. Liu, Y. Tang, F. Yang, C. N. Zhang, D. Cao, G.-J.

Kim, Internet of things based solutions for transport network vulnerability assessment in intelligent transportation systems, *Computers, Materials and Continua*, Vol. 65, No. 3, pp. 2511-2527, September, 2020.

[2] L. Guo, Experience of foreign urban underground space development and utilization (5): Japan underground space development and utilization (5), *Urban planning communication*, pp. 17, September, 2016.

[3] J. Wang, Y. Yang, T. Wang, R. S. Sherratt, J. Zhang, Big Data Service Architecture: A Survey, *Journal of Internet Technology*, Vol. 21, No. 2, pp. 393-405, March, 2020.

[4] J. Zhang, S. Zhong, T. Wang, H-C. Chao, J. Wang, Blockchain-Based Systems and Applications: A Survey, *Journal of Internet Technology*, Vol. 21, No. 1, pp. 1-14, January, 2020.

[5] S. Zhang, Y. Chang, L. Yan, Z. Sheng, F. Yang, G. Han, Y. Huang, J. Xia, Quantum Communication Networks and Trust Management: A Survey, *Computers, Materials & Continua*, Vol. 61, No. 3, pp. 1145-1174, May, 2019.

[6] J. Wang, Y. Gao, W. Liu, W. Wu, S-J. Lim, An Asynchronous Clustering and Mobile Data Gathering Schema Based on Timer Mechanism in Wireless Sensor Networks, *Computers, Materials & Continua*, Vol. 58, No. 3, pp. 711-725, May, 2019.

[7] W. Han, Z. Tian, Z. Huang, L. Zhong, Y. Jia, System Architecture and Key Technologies of Network Security Situation Awareness System YHSAS, *Computers, Materials & Continua*, Vol. 59, No. 1, pp. 167-180, May, 2019.

[8] J. Y. Shen, Characters of UMT Standards and the Assessment Outline, *Urban Mass Transit*, No. 5, pp. 1-6, October, 2003.

[9] H.-H. Yeh, T.-Y. Hsieh, J.-H. Chen, Managing complex engineering interfaces of urban mass rapid transit projects, *Journal of Construction Engineering and Management*, Vol. 143, No. 6, pp. 05017001 (1- 14), June, 2017.

[10] J. H. Zhang, *Research on Train Location Method in Urban Rail Traffic*, Master Thesis, Beijing Jiaotong University, Beijing, China, 2008.

[11] L. Y. Kong, *Study on the Urban Rail Transit Category Selection*, Ph.D. Thesis, Beijing Jiaotong University, Beijing, China, 2009.

[12] Y. Xu, Research on System Mode Selection of Medium or Small Carrying-capacity Urban Rail Transit, Master Thesis, Beijing Jiaotong University, Beijing, China, 2014.

[13] M. J. Farrell, The Measurement of Productive Efficiency, *Journal of the Royal Statistical Society*, Vol. 120, No. 3, pp. 253-290, 1957.

[14] R. Färe, S. Grosskopf, C. A. K. Lovell, The Measurement of Efficiency of Production, *Springer Science+Business Media*, 1985.

[15] R. Färe, S. Grosskopf, M. Norris, Productivity Growth, Technical Progress, and Efficiency Change in Industrialized Countries: Reply, *American Economic Review*, Vol. 87, No. 5, pp. 1040-1043, December, 1997.

[16] R. Färe, S. Grosskopf, Measuring output efficiency, *European Journal of Operational Research*, Vol. 13, No. 2, pp. 173-179, June, 1983.

[17] Y. Zhang, Y. Deng, Y. Liu, L. Wang, Dynamics Modeling and Stability Analysis of Tilt Wing Unmanned Aerial Vehicle During Transition, *Computers, Materials & Continua*, Vol. 59, No. 3, pp. 833-851, 2019.

[18] X. Nie, X. Zou, D. Zhu, Modeling and simulation of entrepreneur individual based on dynamic and complex system computing, *Computer Systems Science and Engineering*, Vol. 34, No. 4, pp. 207-214, July, 2019.

[19] J. Zhang, Personalized product recommendation model based on user interest, *Computer Systems Science and Engineering*, Vol. 34, No. 4, pp. 231-236, July, 2019.

[20] H. Gao, W. Huang, X. Yang, Applying Probabilistic Model Checking to Path Planning in an Intelligent Transportation System Using Mobility Trajectories and Their Statistical Data, *Intelligent Automation and Soft Computing*, Vol. 25, No. 3, pp. 547-559, 2019.

[21] J. Liu, X. Kang, C. Dong, F. Zhang, Simulation of Real-Time Path Planning for Large-Scale Transportation Network Using Parallel Computation, *Intelligent Automation and Soft Computing*, Vol. 25, No. 1, pp. 65-77, 2019.

[22] W. W. Dong, A new method of DEA efficiency ranking for decision making units with independent subsystems, *Journal of Shandong University (Natural Science)*, Vol. 48, No. 1, pp. 89-92, January, 2013.

[23] W. Y. Lin, The Selection and Applicability of Urban Medium-capacity Rapid Tranist, Master Thesis, *Southwest Jiaotong University*, Chengdu, China, 2018.

[24] H. Zhang, Analysis of design points of urban intelligent rail express system, *Intelligent city*, Vol. 4, No. 4, pp. 106-107, February, 2018.

[25] D. Liu, J. Chen, W. J. Song, H. Zhou, C. Peng, Optimization Design of Internal Circulation System in Traction Converter, *High power converter technology*, No. 3, pp. 17-22, June, 2017.

[26] W. W. Liu, Y. Tang, F. Yang, Y. Dou, J. Wang, A Multi-objective Decision-Making Approach for the Optimal Location of Electric Vehicle Charging Facilities, *Computers, Materials & Continua*, Vol. 60, No. 2, pp. 813-834, January, 2019.

[27] S. H. Xie, J. Li, X. F. Huo, C. Song, S. Zhang, Y. Dong, D. Liu, Research on train-ground communication system carrying PIS and CCTV service capability based on LTE, *Modern Urban Transit*, No. 11, pp. 1-5, November, 2018.

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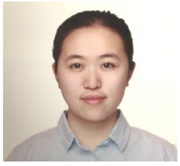

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