Analysis of Factors Affecting the Scale of Urban Rail Transit Construction

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***Abstract*— At present, major cities in the world have reached a consensus on the development of urban transport strategy. With the acceleration of urban rail transit planning and construction, it is imperative to explore the coupling relationship between the urban center system and the development of rail transit. This article uses qualitative and quantitative analysis to explore the key factors affecting the development of urban rail transit. Based on the empirical method, the paper extracted six secondary indicators and 16 tertiary indicators affecting the development of rail transit and conducted qualitative analysis using the feedback mechanism by performing on the secondary quantifiable indicators with factor analysis and extracting two important factors of the urban development scale and urban economic development level which affect the scale of urban rail transit development. Including the macroscopic factors reflecting the level of urban development into the study of the scale of rail transit development can play a guiding role in the long-term planning of the urban rail transit network and can also reduce the waste of duplicated construction and the transformation of the entire line.**

***Index Terms*— Urban Rail transit; Development Scale; Influencing Factors; Principal Component Analysis; Empirical Analysis.**

I. INTRODUCTION

A. Background

With the rapid expansion of transport demand, **traffic problems** have become increasingly prominent and have become the bottleneck of economic development. In some cities, traffic congestion has seriously affected the normal life of citizens. On the other hand, the urban fringe and urbanization in the suburbs will continue to expand, and there will be a large number of long-distance travel needs. It is difficult to adapt to the needs of modern passenger transport simply by conventional **public transportation**.

Judging from the history of urban development in the world's metropolises, rail transit has played a huge role in solving urban traffic congestion and the rational planning and layout of cities. On the one hand, because rail transit construction occupies a considerable proportion of local finances with economic benefits which cannot be seen in the short term, it will seriously increase the financial pressure of local governments. On the other hand, rail transit construction projects are the cities with the largest investment in urban history. Infrastructure construction projects are a century-long plan for a city. Once a circuit is formed, it will be difficult to change. However, there are currently some factors that affect the scale of development of an urban rail transit system, and how large the impact is. There is no comprehensive index measurement system, and there is no **systematic study** on the scale of rail transit development.

B. Research Methodology

Through the appropriate introduction of macro-measurement indicators, the quantitative research method of this article is mainly based on the micro-observation indicators to establish a more comprehensive indicator system. In the selection of mathematical models, relevant data were collected based on the index system established. The final model was determined by comparing the data fitting results of multiple models and the introduction of multi-model experimental methods made the model selection more persuasive. This kind of empirical analysis method expands the scope of factors affecting the scale of development of urban rail transit in the world. On the other hand, it **enriches the current research methods and improves research methods** which has important academic significance.

II. FACTORS

A. All index groups

All indicator groups are divided into **six secondary indicators** and **several tertiary indicators**. The six secondary indicators are the scale of urban development, urban transport demand and supply, urban social and economic development, national policies, technology, and service levels.

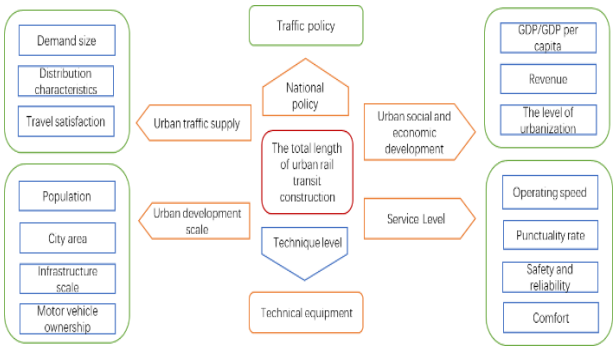

Figure 2-1 Overall indicator group

B. Analysis and Processing of Influencing Factors

It can be seen that from the 16 influencing factors listed in the previous section, some factors can be quantified for quantitative analysis and some factors can only be qualitatively analyzed. These factors do not affect the scale of rail transit development. The following factors were extracted using factor analysis.

Let the $X=(x_1,x_2,\mathrm{L}\ x_p)$ be the observed random vector and $T=(T_1,T_2,\mathrm{L}\ T_m)$ be an unobservable. There are

$$X_i=\mu+aT_1+\mathrm{L}\ a_{im}T_m+\varepsilon_i$$

expressed as an equation:

$$X-\mu=AF+\varepsilon$$

F_i The first common factor, a_{ij} is factor load, F_i is independent of each other and has a variance of 1,independent of each component, the factor model is:：

$$\begin{cases} X_1=a_{11}T_1+a_{12}T_2+\mathrm{L}\ +a_{1m}T_m+\varepsilon_1 \\ X_2=a_{21}T_1+a_{22}T_2+\mathrm{L}\ +a_{2m}T_m+\varepsilon_2 \\ \mathrm{L}\ \mathrm{L} \\ X_n=a_{n1}T_1+a_{n1}T_2+\mathrm{L}\ +a_{nm}T_m+\varepsilon_n \end{cases}$$

III. EMPIRICAL ANALYSIS

According to the index system designed in Chapter 2 and the availability of data, six measurement indicators that represent the factors affecting the scale of rail transit development in an international typical city are selected to perform factor analysis, and the main factors affecting the scale of rail transit development are determined. Select 20 cities such as Tokyo, New York, London, Los Angeles, and Beijing, to conduct empirical analysis.

Through repeated comparisons of multiple experimental results, considering that the results of factor analysis model caused by heteroskedasticity and collinearity between related indicators are not ideal, after some factors and variables are proposed, the following factors and variables are selected for final data processing. See the table below for details:

Table 3-1 Quantification of Influencing Factors of Rail transit Size

Secondary Indicators three indicators	Symbol	Influencing factors three indicators	Symbol
Urban development scale	T_1	Population	X_1
		City area	X_2
		Population density	X_3
		Infrastructure investment ratio	X_4
Urban economic development	T_2	Urban GDP	X_5
Service Level	T_3	Punctuality rate	X_6

Principal component analysis is a multivariate statistical method that linearly combines the original variables to derive new variables called principal components. These principal components retain the original useful information of the original variables and are not related to each other, thus overcoming the deviation caused by the **correlation** between the respective variables. Therefore, this paper uses the principal component analysis method in factor analysis to extract the useful information of the estimated indicators in each sample. The specific analysis process is as follows

Table 3-2 KMO and Bartlett's Tests

KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.551
Bartlett's Test of Sphericity	Approx. Chi-Square	66.981
	df	15
	Sig.	.000

The value of the **KMO test statistic** is 0.551>0.5. According to the metrics given by statisticians, the original variables can be analyzed using factor analysis. Bartlett's Sphericity test statistic is 66.981, and the corresponding Sig value is 0.000<0.05, reaching a significant level. It represents the existence of common factors among the overall correlation matrix and is suitable for factor analysis.

Table 3-3 Common factor variance

Communalities

	Initial	Extraction
Population	1.000	.575
Populationdensity	1.000	.908
Cityarea	1.000	.850
UrbanGDP	1.000	.803
Infrastructureinvestmentratio	1.000	.838
Punctualityrate	1.000	.629

Extraction Method: Principal Component Analysis.

As shown in the variable common degree table, the commonality of all variables is high, and the information loss of each variable is less, indicating that the overall effect extracted in this empirical study is ideal.

The results Gravimetric map shows that from the six original variables, two factors are extracted, and the cumulative interpretation of the original variable information is 76.726%. Therefore, choosing this factor as the main factor for the next step analysis is more appropriate and the analysis effect will be more ideal.

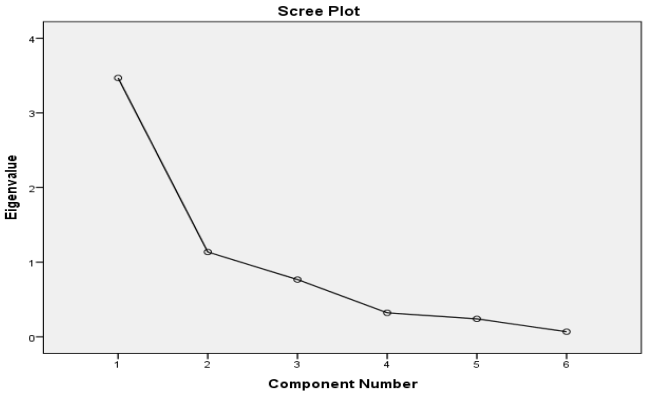

Figure 3-1 Gravimetric map

In addition, from the gravel chart of factor analysis, it can be seen that it is appropriate to extract a number of factors that extract a large amount of information contained in the variables.

Table 3-4 Rotational Component Matrix

Pattern Matrix[a]

	Component	
	1	2
Population	.755	-.033
Populationdensity	.048	.956
Cityarea	.774	-.439
UrbanGDP	.890	-.054
Infrastructureinvestmentratio	.919	.100
Punctualityrate	.783	.207

Extraction Method: Principal Component Analysis.
Rotation Method: Oblimin with Kaiser Normalization.

a. Rotation converged in 4 iterations.

According to the calculation results in the above table, according to the load of the principal component on each index variable, two factors were selected as the main factors affecting the scale of rail transit development. This article follows the approach of Michael and Mark. For multidimensional indicators, it is required in principle that the factor load value of the indicator item in one dimension was as high as possible, and the load value in other dimensions was as low as possible. Therefore, from the rotating factor load matrix, according to the influencing factors corresponding to the variables with the highest contribution rate under each principal component, the main factors affecting the scale of rail transit development were extracted and named as **the scale of urban development** and **the level of urban economic development**. These two factors can explain the information volume of the original variables influencing the scale of rail transit development.

IV. CONCLUSION

Through qualitative and quantitative analysis, we learned that **the scale** and **economic development level** of a city are the two major factors that determine the scale of rail transit construction. The city's GDP and population density are the main impact indicators.

Studying the influencing factors affecting the scale of urban rail transit development will help us grasp the timing of urban development and rail transit planning and construction, and formulate the right rail transit development model that suits our country and city. With the continuous development of the world economy and technology, all countries in the world have paid more attention to the development of rail transit. The scale of rail transit has grown and it has gradually matured in many fields such as construction, investment, operation and management. The world's urban rail transit mainly presents four major development trends: development from developing countries, investment from diversification, operation and marketization, and management.

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