Predicting the impact of urban rail transit construction on employment attractiveness based on the GM(1,1) model: A case study of Guangzhou

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Abstract. Taking Guangzhou, one of the four largest first-tier cities in China, as an example, this paper analyzes the impact of urban rail transit construction on the level of urban employment attraction. Through the establishment of grey model, the relationship between the number of employees in the subway and the whole society is established, and the development trend of Guangzhou's employment attraction in the next five years is predicted. The conclusion is that the number of employees in Guangzhou will reach 10371290 in 2023.

1. Introduction
Since the reform and opening up for more than 40 years, China's economy has undergone profound changes. Under the dual effects of the iterative evolution of technology and the knowledge economy, labor resources, especially advanced labor resources such as talents, have become one of the important strategic resources. The rapid development of cities requires a large number of talents, so the level of employment attractiveness of cities has become one of the increasingly concerned issues of local governments. Urban traffic is the most important infrastructure to maintain the vitality of the city. It is the artery of urban life and restricts the development of urban economy. With the rapid development of urban construction, in order to solve the increasingly severe urban traffic problems, many large and medium-sized cities in China have chosen to accelerate the construction of urban rail transit, which has obvious advantages such as large passenger flow, accurate traffic time control, convenient passenger riding, saving urban space, clean and environmental protection. According to the theory of labor migration, the flow of labor is not random, but purposeful. It is a behavior spontaneously generated in order to improve the current living conditions. The construction of urban rail transit reduces the cost of commuting, and with it comes the improvement of commuting efficiency and the change of commuting methods, which in turn enhances the city’s attractiveness for employment. This article will take Guangzhou, one of the four major first-tier cities in China, as an example to study the impact of urban rail transit construction on employment attractiveness.

2. Literature review
Talents are the fundamental driving force for the economic and social development of the entire country and are closely related to the development of cities. In recent years, domestic scholars have paid great attention to the influencing factors and evaluation methods of urban employment attractiveness. For example, Wang Wenyin and Zhang Jinglin (2019) evaluated the city’s talent attractiveness by establishing an evaluation index system in three aspects: employment, development
opportunities and living environment provided by the city. They concluded that the city’s economic development level and employment opportunities are the main attractive factors. Environmental and natural factors are also important conclusions [1]. Zhang Wei, Jing Weimin, Wang Yujing (2017) built a systematic overall analysis framework of four dimensions: basic environment, career environment, family security, and quality of life to study the talent attraction of first-tier cities in China. The research results show that every 1% increase in traffic congestion will reduce the attractiveness of the city by 0.564%. It is concluded that the congestion problem has become an important consideration for talents in first-tier cities [2].

Regarding the impact of transportation infrastructure on urban employment levels, scholars mostly focus on the attractiveness of high-speed rail to cities. Dong Yanmei and Zhu Yingming (2016) constructed a conceptual model of regional employment growth caused by high-speed rail construction based on the new economic geography theory, and used the PSM-DID method to conduct empirical tests on the employment effect of China's high-speed rail construction, and concluded that high-speed rail construction significantly enhanced the high-speed rail The employment level of cities, especially large cities and eastern and central cities, has widened the employment gap between high-speed rail cities and cities without high-speed rail, but it has a negative impact on high-speed rail cities in western and small cities [3]. Based on the idea of "with or without comparison", Lin Xiaoyan et al. (2015) tested the talent attraction of cities along Wuhan Guangzhou high-speed railway by using factor analysis method, and proposed that the attraction of urban talents with high-speed railway is significantly higher than that without high-speed railway [4].

Regarding the impact of rail transit construction, domestic and foreign scholars' research mainly focuses on the impact on real estate value. Robert Cervero and John Landis (1993), compared a number of measures of market performance between office submarkets located at selected rail transit stations in Washington, DC and Atlanta, with otherwise similar office submarkets lacking transit service [5]. Dean H. Gatzlaff and Marc T. Smith (1993) examined the impact of the development of the Miami Metrorail system on residential property values proximate to its station locations [6]. Domestic scholars Gu Yizhen and Guo Rui (2008) analyzed the impact of urban rail transit on housing prices by using the half logarithm Hedonic Price equation, taking Beijing Batong line as an example [7].

However, few studies have paid attention to the urban employment attractiveness of rail transit construction. This article uses the Guangzhou Metro as an example to analyze the impact of rail transit construction on urban employment attractiveness.

3. Methodology

3.1. Grey relational analysis
Grey relational analysis is one of the important contents of grey system theory. It is widely used in research fields such as society, economy, agriculture, ecology, etc. It has played a huge role in factor analysis, comprehensive evaluation and advantage analysis. In the objective world, the relationship between many factors is gray, which means it is not easy to distinguish which factors are closely related and which factors are not closely related. It is difficult to find the main contradictions, characteristics and relationships. Grey correlation analysis is an analysis method to measure the degree of correlation between various factors based on the degree of similarity or difference between the development trends of various factors.

At present, the calculation models for determining the degree of gray correlation between sequences are mainly as follows: Deng's correlation, gray B-type correlation, C-type correlation, T-type correlation, generalized correlation, gray slope correlation, gray Euclidean Reed correlation degree and so on. Among them, the Deng's grey relational degree algorithm was proposed by Professor Deng Julong. It has the characteristics of clear logic and small amount of calculation, and is suitable for the correlation analysis of grey system time series data and cross-sectional data. In this paper, Deng’s relevance model is used for relevance analysis.
3.2. GM(1,1) grey prediction model

The grey system prediction method is to process the original data, and then establish the grey model, so as to mine, discover and master the evolution law of the system, so as to make a very scientific quantitative prediction of the future state of the system. GM (1,1) grey prediction model is the most widely used in grey system theory. Its main feature is that the modeling mechanism is different from other models, and the data accumulation processing is its original creation. That is, in the data processing of modeling, a series of accumulation and reduction generation of data are needed, and then the rules of data evolution can be found by generating grey series Law. The grey prediction model is an exponential fitting curve based on the least square method, which is compatible with differentiation, difference and index. Therefore, when establishing the model, it can achieve better prediction effect without a large number of time series data, so as to achieve higher accuracy.

Set the original non-negative sequence \( X(0) \), and \( X(0) = [x^{(0)}(1), x^{(0)}(2), \ldots, x^{(0)}(n)] \). The general steps to build a GM(1,1) model using this sequence are shown below.

- The original data \( X(0) \) is cumulatively generated in a first order, and the cumulative generated sequence is

\[
X(1) = [x^{(1)}(1), x^{(1)}(2), \ldots, x^{(1)}(n)]
\]

Among them,

\[
x^{(1)}(k) = \sum_{i=1}^{k} x^{(0)}(i), \quad k = 2, 3, \ldots, n
\]

- Use the first-order cumulative sequence \( X(1) \) generated before to establish the GM(1,1) model.

The whitening differential equation corresponding to the GM(1,1) model of \( X(1) \) is

\[
\frac{dx^{(1)}(t)}{dt} + ax^{(1)}(t) = b
\]

Among them, \( a \) and \( b \) are undetermined coefficients, and the corresponding gray differential equation is obtained as

\[
x^{(0)}(k) + az^{(1)}(k) = b, \quad k = 2, 3, \ldots, n
\]

- Find the values of the parameters \( a \) and \( b \). The parameter list \( \phi = [a, b]^T \) can be determined by the least square method, and \( \phi = [B^T B]^{-1} B^T Y \), among them,

\[
B = \begin{bmatrix}
-z^{(1)}(2) & 1 \\
-z^{(1)}(3) & 1 \\
\vdots & \vdots \\
-z^{(1)}(n) & 1 \\
\end{bmatrix}
\]

\[
z^{(1)}(k) = 0.5[x^{(1)}(k) + x^{(1)}(k-1)]
\]

\[
Y = \begin{bmatrix}
x^{(0)}(2) \\
x^{(0)}(3) \\
\vdots \\
x^{(0)}(n) \\
\end{bmatrix}
\]

- The initial condition is \( \hat{x}^{(1)}(1) = x^{(1)}(1) = x^{(0)}(1) \). The generated sequence model obtained under this condition is

\[
\hat{x}^{(1)}(k) = (x^{(0)}(1) - \frac{b}{a}) e^{-\frac{a}{b}} + \frac{b}{a} k, \quad k = 2, 3, \ldots, n
\]

- Under the initial conditions listed above, the original sequence model can be calculated as

\[
\hat{x}^{(0)}(k) = \hat{x}^{(1)}(k) - \hat{x}^{(1)}(k-1), \quad k = 2, 3, \ldots, n
\]

Among them,

\[
\hat{x}^{(0)}(1) = x^{(0)}(1),
\]

\[
\hat{x}^{(0)}(k) = \left(1 - e^{a k}ight) x^{(0)}(1) - \frac{b}{a} e^{-\frac{a}{b} k}, \quad k = 2, 3, \ldots, n
\]

- When building the model, substituting \( k = 2, 3, \ldots, n \) into the formula one by one will get the fitted value of the GM(1,1) model.

- GM (1,1) model checking

There are three methods to test the effect of gray prediction model: residual test, correlation test and posterior error test method to test the accuracy of the model. In this paper, residual error test and posterior error test are used to test the rationality and accuracy of the model. The test standards are
shown in Table 1.

Predictive value: $\hat{x}^{(0)}(k) = \hat{x}^{(1)}(k) - \hat{x}^{(1)}(k-1)$

Absolute error: $e(k) = |x^{(0)}(k) - \hat{x}^{(0)}(k)|$

Relative error: $\phi(k) = \frac{e(k)}{x^{(0)}(k)}$

Original sequence standard deviation: $S_1 = \sqrt{\frac{\sum [x^{(0)}(i) - \bar{x}^{(0)}]^2}{n}}$

Absolute error sequence standard deviation: $S_2 = \sqrt{\frac{\sum [e(i) - \bar{e}]^2}{n}}$

Calculate the variance ratio: $C = \frac{S_2}{S_1}$

Small error probability: $P = P[|e(i) - \bar{e}| < 0.6745S_1]$

| Accuracy level          | Relative Error | C  | P          |
|-------------------------|----------------|----|------------|
| Good                    | <0.01          | <0.35 | >0.95     |
| Qualified               | <0.05          | <0.50 | >0.80     |
| Reluctantly qualified   | <0.10          | <0.65 | >0.70     |
| Failed                  | ≥0.20          | ≥0.65 | ≤0.70     |

### 4. Empirical Analysis

#### 4.1. Data description

The first line of the Guangzhou Metro was officially opened for operation on June 28, 1997. It is worth noting that as the first cross-city subway in China, Guangfo Metro was opened in November 2010. The opening of the Guangzhou-Foshan Metro has accelerated the progress of Guangzhou-Foshan city, shortened the distance between Guangzhou and Foshan, and made the travel and exchange of visits between Guangzhou and Foshan more convenient, and the phenomenon of cross-city commuting has become increasingly prominent. The term Buddha migratory bird was born. Guangfo migratory birds are defined as people who work in Guangzhou and live in Foshan. It can be seen that the opening of Guangzhou-Foshan Metro, which is a part of Guangzhou rail transit, has had a significant impact on the level of employment attractiveness of Guangzhou.

Based on the above considerations, this article selects total number of employed persons in the whole society, the operating mileage of the Guangzhou Metro, train operation trips, daily passenger flow, and the average daily passenger flow of the Guangfo Line in Guangzhou from 2011 to 2018 as the research basis. See Table 2 for details. The subway data comes from the Guangzhou Metro Annual Report, and the employment data comes from the Guangzhou Statistical Yearbook.

| years | Total Number of Employed Persons at Year-end (person) | Operating mileage (ten thousand kilometers) | Train operation trips (trips) | Daily passenger flow (ten thousand person-times) | Average daily passenger flow of Guangfo Line (ten thousand person-times) |
|-------|-------------------------------------------------------|---------------------------------------------|--------------------------------|-----------------------------------------------|--------------------------------------------------------------------------------|
| 2011  | 7431755                                               | 19307                                       | 1416158                        | 450.59                                        | 10.12                                                                         |
| 2012  | 7512997                                               | 21076                                       | 1526576                        | 507.13                                        | 12.01                                                                         |
| 2013  | 7599295                                               | 23041                                       | 1632703                        | 562.73                                        | 13.42                                                                         |
| 2014  | 7848358                                               | 24980                                       | 1810480                        | 624.08                                        | 14.98                                                                         |
| 2015  | 8109881                                               | 24664                                       | 1805306                        | 659.43                                        | 15.98                                                                         |
| 2016  | 8352580                                               | 25059.18                                   | 1836503                        | 701.73                                        | 23.87                                                                         |
| 2017  | 8623278                                               | 28033.31                                   | 1990218                        | 767.82                                        | 29.37                                                                         |
| 2018  | 8965407                                               | 33534.49                                   | 2318810                        | 829.03                                        | 32.92                                                                         |
4.2. Results and discussion

According to the principle and calculation steps of the gray correlation degree, the correlation degree obtained is shown in Table 3.

| Total Number of Employed Persons at Year-end (person) | Operating mileage (ten thousand kilometers) | 0.758 |
|------------------------------------------------------|---------------------------------------------|-------|
|                                                      | Train operation trips (trips)               | 0.764 |
|                                                      | Daily passenger flow (ten thousand person-times) | 0.680 |
|                                                      | Average daily passenger flow of Guangfo Line (ten thousand person-times) | 0.802 |

Judging from the results in Table 3, the correlation between the Guangzhou Metro operating mileage, train operation trips, daily passenger flow, the average daily passenger flow of Guangzhou-Foshan Line and total number of employed persons in the whole society all exceed 0.65, which is a strong correlation. The construction of urban rail transit has a significant role in promoting the improvement of the attractiveness of urban employment. Among them, the daily average passenger flow of the Guangzhou-Foshan Line has the largest correlation with total number of employed persons in the whole society, reaching 0.802, indicating that the opening of the cross-city subway Guang-Fo Line has significantly affected the employment attractiveness of Guangzhou.

Through the previous analysis of the data, this paper chooses to adopt the gray forecasting model GM(1,1), taking total number of employed persons in the whole society in Guangzhou from 2011 to 2018 as the sample data, and establishing the raw data column of the number of employees in the whole society $x^{(0)}(\tau)$.

$$x^{(0)}(\tau) = (x^{(0)}(1), x^{(0)}(2), \ldots, x^{(0)}(8)) = (7431755, 7512997, \ldots, 8965407)$$

Calculate the grade ratio $\sigma(k)$ all fall within the acceptable coverage $X = \left(e^{-\frac{k}{\tau+1}}, e^{\frac{k}{\tau+1}}\right)$, the grade ratio is passed, it can be carried out Next step.

Calculated by programming in Matlab R2019a software, the parameters to be estimated $a = -0.0305$, $u = 7080068.2161$, the time response function of the GM(1,1) model is:

$$x^{(1)}(\tau + 1) = 239565139.13 \cdot e^{0.0305k} - 232133384.13$$

Substituting the formula to calculate the predicted value of employment in Guangzhou from 2011 to 2018, see Table 4.

| years | Total Number of Employed Persons at Year-end (person) | Predictive value $\hat{x}^{(0)}(k)$ | Absolute error $\varepsilon(k)$ | Relative error $\phi(k)$ |
|-------|------------------------------------------------------|-------------------------------------|-------------------------------|-------------------------|
| 2011  | 7431755                                              | 7431755                             | 0                             | 0                       |
| 2012  | 7512997                                              | 7418816                             | 94181                         | 1.2536%                 |
| 2013  | 7599295                                              | 7648244                             | 48949                         | 0.6441%                 |
| 2014  | 7848358                                              | 7884766                             | 36408                         | 0.4639%                 |
| 2015  | 8109881                                              | 8128603                             | 18722                         | 0.2309%                 |
| 2016  | 8352580                                              | 8379981                             | 27401                         | 0.3281%                 |
| 2017  | 8623278                                              | 8639132                             | 15854                         | 0.1839%                 |
| 2018  | 8965407                                              | 8906298                             | 59109                         | 0.6593%                 |

The comparison between historical data and simulated data is shown in Figure 1.
The accuracy test of the model shows that the maximum relative error between the predicted value and the actual value is 1.2536%, most of which are below 1%. In addition, $C=0.0895<0.35$, $P=1>0.95$, indicating that the prediction results of this paper have high credibility, and the model can be used for prediction.

The GM (1,1) prediction model established is used to predict total number of employed persons in Guangzhou in the next five years, as shown in Table 5.

| years       | 2019       | 2020       | 2021       | 2022       | 2023       |
|-------------|------------|------------|------------|------------|------------|
| Total Number of Employed Persons at Year-end (person) | 9181726    | 9465672    | 9758399    | 10060178   | 10371290   |

5. Conclusion

Through the grey correlation analysis of the relevant factors and economic indicators of Guangzhou metro construction, it is found that train operation trips, the daily average passenger flow of Guangzhou Foshan line and total number of employed persons in the whole society in Guangzhou are highly correlated. It shows that the construction of Metro has a great impact on the level of urban employment attraction. As a cross-city subway between Guangzhou and Foshan, Guangzhou Foshan line promotes the cross-city commuting phenomenon, so it is closely related to the employment attraction of Guangzhou. According to the rail transit network planning of Guangzhou, there are 23 urban rail transit lines planned in the long term, with a total length of about 1025 kilometers. The planning department of Guangzhou has planned and added an urban circle express network with Guangzhou as the center and radiating the surrounding cities to build a one-hour rail economy and commuter service circle centered on Guangzhou. In the future, a pattern of "one network, one ticket and one cluster of cities" will be formed. After the integration of Bay District Rail Transit, people's travel will be more convenient and the travel cost will be greatly reduced. Therefore, the employment attraction of Guangzhou with a high level of economic development will continue to rise in a short period of time.

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