Predicting the influence of Guangfo Metro on the economic level of Foshan City Based on the GM(1,1) model

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Abstract. Taking Foshan as an example, this paper analyzes the degree of correlation between Guangzhou-Foshan subway construction and the city’s economic level, and establishes a GM (1,1) prediction model by using the gray prediction method to predict the development trend of Foshan’s GDP in the next five years, and concludes that 2024 Foshan’s simulated regional GDP will reach 1507361.527 million yuan. The research results of this article will provide a theoretical basis for the formulation of Foshan’s urban planning and construction policies.

1. Introduction

As the country pays more and more attention to the construction of urban transportation infrastructure, the subway, as a fast and convenient means of transportation, plays an important role in urban construction. China began to construct subways in the 1960s, and now large and medium cities such as Shanghai, Guangzhou, and Beijing have built subway networks. The impact of the subway on the city not only alleviates the traffic congestion problem, shortens the transit time, brings convenience to residents' travel, but also stimulates the urban economic development. Taking Guangfo Metro as an example, by measuring the correlation between the subway and the city's economic level, the close relationship between the two is determined, and the gray model is further used to measure the impact of the subway on the city's economic level.

2. Literature review

Rail transit improves the speed and efficiency of inter-city transportation in the metropolitan area, saves the time cost of inter-city travel, shortens the space-time distance between cities, and promotes the flow of talents and capital. It is important for rail transit and regional economic growth. As far as the relationship is concerned, scholars have also conducted extensive and in-depth discussions. Among them, Jin (2000) took South Korea as an example to study the impact of rail transit on urban development [1]; Anderson (2008) studied the increase in urban accessibility caused by rail transit construction, which in turn has an impact on real estate prices [2]. In China, Chinese scholar Zhang Jun (2017) based on the research of county-level local governments also found that the opening of high-speed rail can promote the economic growth of county-level cities [3]; Wang Yufei and Ni Pengfei (2016) further investigated the economic growth of rail transit. The results of the study found that after the opening of rail transit, the spillover effect of China’s inter-regional economic growth has increased significantly, which verifies
the structural effect of transportation infrastructure [4]. However, these studies mainly focus on the theoretical level, and have less research on specific cities and their subways.

This study uses the grey model as an analysis tool to construct a theoretical model to reveal the correlation between Guangfo Metro and Foshan’s economy. On this basis, further analyze the correlation between various influencing factors and establish a gray model. Finally, forecast the changes in Foshan’s GDP from 2020 to 2024 based on the model.

3. Relevance analysis and grey prediction model

3.1. Grey relational analysis

- Determine the analysis sequence

\[ X_0 = \{x_0(k), k = 1, 2, \ldots, n\} \]

\[ X_i = \{x_i(k), k = 1, 2, \ldots, n\}, i = 1, 2, \ldots, m \]

- Non-dimensionalization of variables

Since the data in each factor column may have different orders of magnitude, in order to ensure the reliability of the data column, the data sequence must be dimensionless. The methods used usually include the initial value method and the mean value method. This article uses the mean value method to perform the data column Nondimensionalization.

\[ x_i' = \frac{1}{n} \sum_{k=1}^{n} x_i(k) \]

- Difference sequence

Calculate the absolute difference between the corresponding elements of each index series and the reference series, and find the maximum and minimum differences, which are recorded as the maximum difference M and the minimum difference m.

\[ \Delta_{ij}(k) = |x_i'(k) - x_j'(k)|, k = 1, 2, \ldots, n ; j = 1, 2, \ldots, m \]

- Find the correlation coefficient

\[ r(x_i'(k), x_j'(k)) = \frac{m + \rho M}{\Delta_{ij}(k) + \rho M}, k = 1, 2, \ldots, n ; j = 1, 2, \ldots, m \]

In the formula, \( \rho \) is the resolution coefficient, and \( \rho \epsilon [0,1] \), the smaller the \( \rho \), the more the difference between the factors can be reflected. In general, the value between \( \rho \in [0,0.5] \) is taken, and \( \rho = 0.5 \).

- Calculate the degree of relevance

\[ r_{ij} = r(x_i, x_j) = \frac{1}{n} \sum_{k=1}^{n} r(x_i'(k), x_j'(k)) \]

According to the evaluation criteria of the gray correlation degree: 0 to 0.35 is weak correlation, 0.35 to 0.65 is medium correlation, and 0.65 to 1 is strong correlation

3.2. GREY PREDICTION MODEL

The gray system forecasting principle is to mine and sort the original data to reduce the randomness of the original data and show a certain regularity trend, and then analyze the correlation between various influencing factors, establish a gray dynamic model.

- Select sample data, create data column \( x^{(0)} \)

\[ x^{(0)} = (x^{(0)}(1), x^{(0)}(2), \ldots, x^{(0)}(n)) \]
Detection level than $\sigma(k)$

$$
\sigma(k) = \frac{x^{(0)}(k)}{x^{(0)}(k-1)}, \ k = 2,3,\ldots, n
$$

Check whether all the level ratios fall within the acceptable coverage $X = \left( e^{-\frac{2}{n+1}}, e^{\frac{2}{n+1}} \right)$, if not all fall within $X$, make a corresponding change $y^{(0)}(k) = x^{(0)}(k) + c, k = 1,2,\ldots, n$ so that the sequence meets the above conditions.

First-order Accumulation of the Original Sequence

$$
x^{(1)}(1), x^{(1)}(2),\ldots, x^{(1)}(n)
$$

$$
x^{(1)}(k) = \sum_{i=1}^{k} x^{(0)}(i)
$$

Establish a Whitening Equation for the GM(1,1) Model

$$
\frac{dx^{(1)}(t)}{dt} + ax^{(1)}(t) = u
$$

Among them, $a$ is called the development gray number, which represents the development trend between the first-order cumulative sequence $x^{(1)}$ and the original sequence $x^{(0)}$; $u$ is called the endogenous control gray number, which reflects the relationship between the data. At the same time, the derivative of equation (5) can be expressed as:

$$
\frac{dx^{(1)}(k+1)}{dt} = x^{(1)}(k+1) - x^{(1)}(k), k = 2,3,\ldots, n
$$

$x^{(1)}$ is replaced with the average of two adjacent data, and the original whitening equation is transformed into:

$$
[x^{(1)}(k+1) - x^{(1)}(k)] \alpha + 0.5[x^{(1)}(k+1) + x^{(1)}(k)] = \mu, k = 2,3,\ldots, n - 1
$$

$$
-0.5[x^{(1)}(k+1) + x^{(1)}(k)] \alpha + 1 \mu = x^{(0)}(k + 1)
$$

Construct Matrix $B$ and Data Vector $Y_n$

$$
B = 
\begin{bmatrix}
-1/2 \left( x^{(1)}(1) + x^{(1)}(2) \right) & 1 \\
-1/2 \left( x^{(1)}(2) + x^{(1)}(3) \right) & 1 \\
\vdots & \vdots \\
-1/2 \left( x^{(1)}(n-1) + x^{(1)}(n) \right) & 1
\end{bmatrix}

Y_n =
\begin{bmatrix}
x^{(0)}(2) \\
x^{(0)}(3) \\
\vdots \\
x^{(0)}(n)
\end{bmatrix}
$$

The least square method is used to find $\epsilon = (B^T B)^{-1}B^T Y = \begin{bmatrix} a \\ \mu \end{bmatrix}$

The Time Response Sequence of the GM(1,1) Model is

$$
x^{(1)}(k+1) = \left( X^{(0)}(1) - \frac{\mu}{a} \right) e^{-ak} + \frac{\mu}{a}, k = 1,2,\ldots, n
$$

Perform differential operations on the response function

$$
\hat{x}^{(0)}(k+1) = \hat{x}^{(1)}(k+1) - \hat{x}^{(1)}(k), k = 1,2,\ldots, n
$$

GM (1,1) model checking

Grey prediction test generally includes residual test, correlation test and posterior error test. This article uses residual test.

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

Absolute error: $\epsilon(k) = |x^{(0)}(k) - \hat{x}^{(0)}(k)|$
Relative error:
\[ \phi(k) = \frac{\varepsilon(k)}{x^{(0)}(k)} \]

4. PRACTICAL USE OF THE MODEL

4.1. Basic data source

The Foshan Metro has been in trial operation since 2010, so the GDP, GDP per capita, the number of trains on the Guangzhou-Foshan Metro and the average daily passenger flow in Foshan from 2011 to the present are selected as the research basis, as shown in Table 1.

There are two sources of data: first, the relevant yearbook annual report collects data; second, the official website statistics website.

| years | GDP (ten thousand yuan) | Per capita GDP (yuan) | Number of trains on the line (trains) | Average daily passenger flow (10,000 people) |
|-------|------------------------|-----------------------|--------------------------------------|-------------------------------------------|
| 2011  | 62596821               | 86759                 | 12                                   | 10.1                                      |
| 2012  | 66771742               | 92145                 | 14                                   | 12.1                                      |
| 2013  | 71174758               | 97784                 | 14                                   | 13.42                                     |
| 2014  | 75613740               | 103253                | 15                                   | 14.98                                     |
| 2015  | 81336599               | 110054                | 19                                   | 16                                        |
| 2016  | 87577206               | 117606                | 26                                   | 24                                        |
| 2017  | 93985162               | 124324                | 27                                   | 29.4                                      |
| 2018  | 99358844.99            | 127691                | 31                                   | 32.92                                     |
| 2019  | 107510200              | 131775.3              | 33                                   | 53.03                                     |

4.2. Model substitution and analysis

According to the above analysis of the grey relational degree principle and steps, the relational table 2

| Number of trains on the line (trains) | GDP (ten thousand yuan) | Per capita GDP (yuan) |
|--------------------------------------|------------------------|-----------------------|
| 0.852                                | 0.827                  |
| Average daily passenger flow (10,000 people) | 0.804                  | 0.788                 |

From the results in Table 2, the highest correlation is the correlation between the number of trains on the line and the regional GDP, reaching 0.852, which has the most significant impact, indicating that the increase in subway passenger traffic will significantly promote the regional economy It shows that subway construction has a significant impact on the economy.

The previous data shows that the regional GDP has the highest correlation with the online trains. We choose the gray forecast model GM(1,1). To facilitate the comparison of forecasts, choose the 2011-2019 GDP in Foshan as the sample data and establish the original Data area GDP data column \( x^{(0)} \).

\[
x^{(0)} = \left( x^{(0)}(1), x^{(0)}(2), \ldots, x^{(0)}(9) \right) = (62596821, 66771742, \ldots, 107510200)
\]

Calculate the grade ratio \( \sigma(k) \) all fall within the acceptable coverage \( X = \left( e^{-\frac{2}{n+1}}, e^{\frac{2}{n+1}} \right) \), the grade ratio is passed, it can be carried out Next step.

Calculated by programming in Matlab20 software, the parameters to be estimated \( a = -0.0683 \), \( u = 59876572.6010 \), the time response function of the GM(1,1) model is:

\[
x^{(1)}(k + 1) = 939,266,990.8535871e^{-0.0683k} + 876670169.8535871
\]

Substituting the formula to calculate the forecast value of Foshan's GDP from 2011 to 2019, see Table 3.

| years | GDP (ten thousand yuan) | Predictive value | Absolute error \( \varepsilon(k) \) | Relative error \( \phi(k) \) |
|-------|------------------------|------------------|---------------------------------|---------------------------|

4
The comparison between historical data and simulated data is shown in Figure 1.

![Comparison of historical data and analog data](image)

Figure 1. A Comparison of historical data and analog data

After model testing, the maximum relative error between the predicted value and the actual value is 0.6869%, most of which are below 0.05, indicating that the prediction results in this paper have high credibility and the model can be used for prediction.

The established GM(1,1) forecast model is used to predict the economic level of Foshan in the next 5 years, as shown in Table 4.

| years | 2020         | 2021         | 2022         |
|-------|--------------|--------------|--------------|
|       | Simulated GDP (ten thousand yuan) | 114689945.9916 | 122800000.2735 | 131483539.7017 |

| years | 2023 | 2024 |
|-------|------|------|
|      | Simulated GDP (ten thousand yuan) | 140781117.0520 | 150736152.7029 |

5. Conclusion
Through the gray correlation analysis of the relevant factors and economic indicators of Foshan's subway construction, it shows that the number of trains on the line has the largest correlation with the regional GDP, indicating that subway construction has a greater impact on economic development. At present, Foshan Metro operates one metro line, namely Guangfo Line (Foshan Metro Line 1). There are 2 lines under construction, including Line 2 and Line 3, covering a total of more than 120 kilometers and 47 stations. In the long-term plan, Foshan Metro will form a rail transit network with 14 operating lines and a total length of more than 572 kilometers. The formed subway network will greatly improve Foshan's transportation network, make it more convenient for people to travel, and also have a certain role in promoting economic growth.
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References
[1] Kim K S. High-speed rail developments and spatial restructuring - A case study of the Capital region in South Korea[J]. Cities, 2000, 17(4):251-262.
[2] Andersson D.E. O.F. Shyr J. Fu. Does High-speed Rail Accessibility Influence Residential Property Prices? Hedonic Estimates from Southern Taiwan [J]. Journal of Transport Geography 2010(18): 166-174.
[3] Zhang Jun. High-speed rail construction and county economic development: research based on satellite light data [J]. China Economic Quarterly, 2017(04):301-330.
[4] Wang Yufei, Ni Pengfei. Economic growth spillover and regional space optimization under the influence of high-speed railway [J]. China Industrial Economics, 2016, 000(002):21-36.
[5] Guo Xiuyun. Application of Grey Correlation Method in Regional Competitiveness Evaluation [J]. Statistics & Decision, 2004(11):55-56.