Chapter 37
Long Time Forecasting of Rail Transit Passenger Volume

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Abstract The theory and application of railway passenger traffic volume (RPTV) forecasting is one of the focuses in the research areas of traffic transportation. RPTV forecasting is an important responsibility of the railway transportation management departments, RPTV is influenced by multiple factors, and the action mechanisms of these factors are usually unable to be described by accurate mathematical linguistic forms, so the theory and method of RPTV forecasting remains a focus in research all the time. And RPTV has a great important in the choosing of route, the construction of station before a new line was built, and the operation after the line was using.

Keywords Railway • Passenger traffic volume • Forecasting • Long time

37.1 Introduction

With the reforming of China's railway passenger market, especially in recent years, China's highway, civil aviation has been greatly developed through the open management, while railway transportation has been challenged powerfully, the competition between different modes of transportation will become increasingly intense. Highway, civil aviation, pipeline transportation and other transportations, are intended to be further extended to the advantaged area of traditional railway, and the quality, efficiency of transportation will be the focus of competition in the future.

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In order to further improve the competitiveness and economic efficiency of railway, full system analysis research need to be done to make decisions for market operating.

37.2 The Important of Railway Passenger Traffic Volume

According to China medium and long-time railway network plan, in order to solve the problem of insufficient trunk railway transport capacity, the national will build Passenger Dedicated Lines (PDL), which will be more than 12,000 km, between capital cities and large and medium cities before 2020. The project of the PDL will be involved with operation, organization, station layout and built, passenger transfer and relief and so on inevitably, all the aspects referred above have a relation to the passenger forecasts. Therefore, the passenger forecast for PDL is becoming more and more important nowadays.

The RPTV forecasting can offer scientific basis for the establishment of policy and making of transportation development plan.

37.3 Long Time Foresting for the Train Passenger

According to foreign experiences, after the PDL was built, the passenger volume will increase dramatically in short time, this kind of phenomenon is different from the flow increased year by year pattern. For example, Tokaido Shinkansen in Japan after 1 year opening, the passenger volume dramatically increased 52 % between Shizuoka and Hamamatsu, compare the condition before opening, Tokaido Shinkansen traffic soared 66 % 2 years after opening [1]. The remarkable change should be taking into full account when make long-term forecasting in PDL.

Considering the passenger flow's structure of the PDL, the passenger flow can be divided into three parts: trends passenger flow, induced broker flow and transfer passenger flow. The influence factors of these three flows are not the same, the characteristics of the passenger flows change also have difference, and in the operation of the PDL in different periods three constitutions ratio will change. If the three parts were taken as a whole to analysis in the study of the passenger flow forecast, it will lead to a large deviation to prediction, so in my paper, I make different models apply to the three different flows, so that the result could be more close to the real situation.

37.3.1 Trends Passengers Flow

Trends passenger flow is a flow that with the increasing of population and economy in a country or a region, more and more passengers choose railway to travel.

At present, because of overload in transportation capacity, the main railway lines of China, such as Beijing-Guangzhou, Beijing-Shanghai, Beijing-Harbin and Longhai lines, all of the main lines cannot afford to meet the growth of the passenger travel demand [2]. On this basis, the government of China decided to build PDL to separate the freight transport and passenger transportation, and with the building of PDL, the flow which belong to the existing lines will shift to the PDL, and this trends passenger flow shows a continuous gradual increase, and in the model choosing I thought the grey system theory is good.

37.3.1.1 Grey System Theory

Grey System Theory is a study on indeterminate systems based on small samples and little information [3]. It deals with the original data and creates Grey Model to discover the development rules of the systems. The merits of this method are its easy use and high precision. Especially, it can assure that the number of samples and the volume of calculation will not increase with the time. Whereas its shortcoming lies in its unreliable forecasting result, especially when data samples are few and the fluctuation of data is obvious.

37.3.1.2 Modeling and Procedures

Trends passenger flow is an order bounded set along with the development of economy, there are some unknown rules between it, considering the passenger transportation system is a huge Grey System, Grey Model is very suitable to predict transport volume [2–4].

Step 1: Collect the passenger traffic volume original data (OD matrix), and get the original series:

$$q^{(0)} = \left\{ q^{(0)}(1), q^{(0)}(2), q^{(0)}(3), \ldots, q^{(0)}(t) \right\},$$

Where $q^{(0)}(t)$ ($t = 1, 2, 3, \ldots, t$) is respectively the passenger traffic volume of existing lines, which collected from the historical data of the first n years.

Step 2: Applying AGO (Accumulated generating operation) on $q^{(0)}$, provided that:

$$q^{(1)} = \left\{ q^{(1)}(1), q^{(1)}(2), q^{(1)}(3), \ldots, q^{(1)}(t) \right\},$$

Where $q^{(1)}(t) = \sum_{k=1}^{t} q^{(0)}(k), \quad t = 1, 2, 3, 4, \ldots, n$

Step 3: Provided sum matrix B and constant vector Y_T:

$$B = \begin{bmatrix} -\frac{1}{2}\left(q^{(1)}(1) + q^{(1)}(2)\right) & 1 \\ -\frac{1}{2}\left(q^{(2)}(1) + q^{(1)}(3)\right) & 1 \\ \cdots \quad \cdots & \\ -\frac{1}{2}\left(q^{(1)}(t-1) + q^{(1)}(t)\right) & 1 \end{bmatrix};$$

$$Y_t = \left\{q^{(0)}(2), q^{(0)}(3) \ldots q^{(0)}(t)\right\}^T$$

Step 4: Perform a least squares estimate for the parameters, the simulated parameters can be obtained that

$$a \wedge = [a, u]^T = \left(B^T B\right)^{-1} B^T Y_t$$

Where a and u are parameters.

Step 5: figure out $q^{(0)}(t+1) = -a\left(q^{(0)}(1) - \frac{u}{a}\right)e^{-at}$

Now we get the trends passenger flow.

37.3.2 Induced Broker Flow

Induced broker flow means as a result of the traffic facilities and other hardware change such as high speed railways and PDL build, or software conditions change such as improvement of traffic control measures and policy guidance, people produce more wishes to travel, then a kind of flow is formed. For example, the Beijing-Tianjin Express Railway makes people travel between Tianjin and Beijing more frequent. This kind of passenger flow express three steps: gradually formed, rapid growth, gradually stable.

In the paper, the road traffic of the gravity model is applied to forecast the induced broker flow, all the influence factors are called potential factors with same parameters in the paper. There are many affecting factors in the induced broker flow forecasting, such as resident population, industrial production, cultural exchange, and so on.

37.3.2.1 The Road Traffic of the Gravity Model

Gravity models can be used in cases such as new rail station or construction of a new railway line, for which there are obviously no statistical data.

According Gravitation traffic accessibility model (Casey 1995) [5–6], we get the original model $q_{ij} = k\frac{P_i A_j}{R_{ij}^2}$ [5–6], in the days coming some scholars have further researched on the model and get a modificatory one $q_{ij} = k\frac{P_i^{\alpha} A_j^{\beta}}{R_{ij}^{\gamma}}$.

Where P_i, A_j, R_{ij} have great influences on the q_{ij}, with the same theory, we can apply this model to the forecast of induced broker flow of railway, while equation ** presents a too simplistic analogy with gravity law, for this reason, we make a little change in the former model and get a new one as below [2]:

Suppose city i and city j, and the passenger flow between these two cities is P_{ij}, the formula as follow:

$$P_{ij} = k\frac{\left(E_i \times E_j\right)^{\alpha} + \left(F_i \times F_j\right)^{\beta}}{R_{ij}^{\gamma}},$$

Where:

E_i and E_j is the GDP of city i and city j,
F_i: population of city i,
F_j: population of city j,
α, β, γ, k: proportionality factor,
γ: parameter of calibration. Various studies estimated values of the parameter γ to be between 0.6 and 3.5.
R_{ij}: generalized cost of rail transport between cities i and city j, it is the comprehensive reflection of transportation service.

$$R_{ij} = C_{ij} + T_{ij}W + S_{ij}$$

Where C_{ij}: fee cost of rail transport between cities i and city j,
T_{ij}: time cost of rail transport between cities i and city j,
W: time value (dollar per hour),
S_{ij}: passengers fatigue.

37.3.2.2 Modeling and Procedures

Step 1: Get the population data and its GDP value between each section of the line.
Step 2: Use the questionnaire method etc. to get the transport impedance between each section before a PDL was built.
Step 3: Make log conversion for improved gravity model, with the multiple regression method to
Step 4: The Step 3 can be worked out the passenger flow for existing lines.
Step 5: Obtained the transportation impedance for the PDL in planning, from the model built result to obtain PDL flow after it in operation.
Step 6: The difference in value between Step 5 and Step 4 can be concluded that the proposed increase induced broker flow for passenger.

37.3.3 Transfer Passenger Flow

The transfer passenger flow means with the promotion of the railway system, some passengers who used to take the other travel ways tend to railway system, so we should also take this passenger flow in account [1].

37.3.3.1 Sharing Rate Model

First, the most important part is we should ascertaining the sharing rate of the passenger flow of the railway in the research of forecast model of the passenger flow volume which involves all the available traffic model. Using other city's experience is the most common way to get the original data, and the influence scope of railway should be taken in account [7]. Here we build a model which reflects the probability of choosing the certain traffic modes. The model is as follow:

$$w_i = \frac{\exp(v_i)}{\sum_j \exp(v_i)}$$

Where w_i is the probability of choosing this traffic modes; i, j is the kinds of traffic modes; V_i, V_j is the utility function of taking the traffic modes i, j;

In the forecast model, the main task is to distinguish the passenger flow of choosing the railway and other modes. Whether selecting the railway is related to the accessibility of the railway station and the time of resident's trip. So its utility function is as follow:

$$v_i = x_1 C_i + x_2 T_i + \varepsilon$$

Where C_i, T_i is respectively the convenient and the time cost of traffic model; x_1, x_2 is the variable of the utility function; ε submits to normal distribution.

This model takes the accessibility and trip time & distance as the variable of the utility function, and reflects the sharing rate of railway passenger flow volume will change with the layout of the station and the distance of railway station. The distance to the station is shorter; the accessibility is better; the sharing rate is bigger. This meets the characteristic of railway passenger flow distribution.

37.3.3.2 Modeling and Procedures

Proposed there were n different modes of transportation in a transportation line from i to j, and the total traffic volume was A_{ij}.

Step 1: Get the effectiveness v_i from the survey of different modes of transportation
Step 2: According to the model, work out the share rate w_i of different modes of transportation.

Step 3: Figure out passenger flow A_{ij}^{i} based on A_{ij} and w_i.

Step 4: Obtain the new effectiveness $v_i^{'}$ when mode i, one of the transportation modes, had improved its service.

Step 5: According to the model, figure out the share rate of $w_i^{'}$ different modes of transportation.

Step 6: Suppose the situation that the total traffic volume has no change, we can figure out the passenger flow $A_{ij}^{i'}$ in mode i after its service had improved.

Step 7: And now the difference between step 6 and step 3 is the transfer passenger flow.

37.4 Conclusion

With the results of Sect. 37.3.1.2 step 5, Sect. 37.3.2.2 step 6 and Sect. 37.3.3.2 step 7, we can get the forecasting of long-term passenger flow of PDL. At the different period operation of PDL, the passenger flow is different. In detail, at the beginning the main part is trends passenger flow; when the PDL has operated for a time, the induced broker flow and transfer passenger flow will take more weight, while the trends passenger flow may not change a lot.

So I would like to say the model built to forecasting long-term passenger flow can reflect the real situation in some degree.

Rail transit is a huge, complex system which has the feature of irreversibility, once the line was built on change was available.

Above all, China's high-speed railway and the construction of the rail transit development of China will occupy an important position in the future, this part will occupy a great share of the market, and the government will donate huge financial support into the research, as a result academic research in the area of rail transit will also have a great prospect.

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