ISSN 1330-3651 (Print), ISSN 1848-6339 (Online)
https://doi.org/10.17559/TV-20240113001265
Original scientific paper

Research on Passenger Flow Forecast of Tourist-dedicated Train Based on System Dynamics

Yuanding CUI*, Yinzhen LI, Changxi MA

Abstract: Reasonable and effective passenger flow forecasting is a prerequisite for the initial investment planning of tourist-dedicated train projects, improving operational efficiency and market competitiveness. Based on the classification and analysis of tourist-dedicated train passenger flow, this paper introduces the theory of system dynamics to forecast the passenger flow of tourist-dedicated train. The system dynamics equation of passenger flow forecasting is constructed, and the causal loop diagram and system flow diagram of the forecasting system are analyzed. The development of tourist-dedicated train passenger flow is forecasted by two examples of different scales. The research results show that the system dynamics method is feasible and applicable for the passenger flow forecasting of the tourist-dedicated train, and the introduction of this method provides a new theoretical reference for the study of this problem.

Keywords: passenger flow forecast; railway tourism; system dynamics; tourist-dedicated train

1 INTRODUCTION

In recent years, the scale of China's railway network has been accelerating, the number of tourists driven by the railway has increased significantly, which has greatly promoted the vitality upgrading of the tourism industry. Choosing railway as the main means of transportation for tourism has incomparable advantages over other means of transportation. In addition to convenient and fast arrival and low fares, it also has the characteristics of flexible train selection, comfortable travel environment and can enjoy scenery along the train line. Different from the traditional railway tourism train, the tourist-dedicated train is a tourism product of "integration of tourism and transportation." It has both tourism and transportation attributes. In addition to achieving the goal of transporting passengers, it also includes various tourism services for dedicated train passengers. From this point of view, the tourist-dedicated train can be defined as a full range of tourism service products, including transportation, provided to the tourist population, operated by railway transport enterprises. The railway tourism market has great market potential. It is of great meaning to operate tourist-dedicated trains and launch corresponding dedicated train products. The passenger flow data of tourist-dedicated train is an important data basis for the preparation of dedicated train transportation plan, capacity scheduling, personnel organization, economic evaluation and operation effect summary. Through the forecasting research, it reveals the formation and development law and change trend of the passenger flow of the tourist-dedicated train, analyzes the development ways and conditions of the passenger flow of the dedicated train, and judges the future state of the passenger flow of the dedicated train, so as to put forward the corresponding management decision-making scheme. Therefore, the forecasting of the transportation demand of the tourist-dedicated train is not only an important basis for the railway transportation department to formulate and optimize the operation plan and product train line plan of the tourist-dedicated train, but also an important prerequisite for the railway enterprises to provide various service guarantees for the dedicated train passengers.

2 LITERATURE REVIEW

In the current research, there are many related researches on passenger flow forecasting, which are summarized from three aspects: railway passenger flow forecasting, tourism passenger flow forecasting, and research methods.

(1) Railway passenger volume forecasting.

Tsai, Wei et al. and Wang et al. proposed that neural network structure can be used to forecast short-term passenger demand in railway and subway operation planning [1-3]. Jiang et al. believe that the forecasting of high-speed railway passenger flow takes into account the recent (such as next week, next month) daily demand changes, and is the most critical step in the planning, operation decision-making and dynamic operation adjustment of high-speed passenger railway. A short-term demand forecasting method based on grey theory combined with vector machine model is proposed [4]. Jiao et al. [5] believe that short-term passenger flow forecast is a prerequisite for rational operation and management of rail transit system. A modified Kalman filter model for passenger flow forecast of Beijing rail transit is proposed [5]. The multivariate system dynamics forecasting method proposed by Yin is used to forecast traffic time series. This method has broad application prospects in forecasting [6].

(2) Tourism passenger flow forecasting.

Kon et al., Chen et al. believed that the accurate forecasting of tourist flow is very important for perceiving potential tourism demand and evaluating the level of tourism infrastructure, and that there is uncertainty in tourist flows [7, 8]. Cho used time series forecast technology to forecast the travel demand to Hong Kong [9]. Sun et al. believe that in view of the impact of tourism market volatility on forecasting accuracy, the grey-Markov chain grey model is used to focus on small sample observations and exponential distribution samples [10]. Yao believes that the focus of economic development in tourist areas includes tourist sources and tourism demand forecasting, and proposed a paired neural network forecasting model [11].

(3) The application of system dynamics in forecasting.

System dynamics is a system simulation method founded by Professor Jay W. Forrester and used for management optimization. After years of development, it has become a research tool for system science and management science [12, 13]. At present, the system dynamics model has been applied to the forecasting and simulation research in many fields such as carbon neutralization, air transportation, railway transportation, etc.

Li et al. believed that the system dynamics method can effectively predict the power consumption, and the prediction results can provide data basis for power dispatching [14]. Diana et al. forecasted the number of flights and the number of passengers in the airport through the method of system dynamics, as the basis for the reconstruction and expansion of the airport station hall and the determination of the scale of runway expansion [15]. Suryani et al. believed that factors such as fare, economic level, service quality, number of incoming flights, and regional population can constitute a passenger flow forecasting system for aviation hubs, and forecast passenger flow through system dynamics methods [16]. Feng et al. [17] analyzed the influencing factors of railway freight transportation, applied system dynamics to the forecast of railway freight transportation capacity, and constructed a railway freight volume system model. Mou [18] considered that the railway passenger flow is a complex multi-factor system, and used the system dynamics modeling method to forecast the annual flow of China's high-speed rail.

3 TOURIST-DEDICATED TRAIN PASSENGER FLOW CLASSIFICATION

The passenger flow of tourist trains can be divided into the following three categories. The sum of the three types of passenger flow is the total passenger flow.

(1) Trend passenger flow

Trend passenger flow refers to the relatively stable passenger flow under the influence of factors such as the economic level, population, consumption level and tourism habits of the source area. This part of the passenger flow crowd has tourism habits and hobbies, and has the economic ability of the crowd, or with tourism-related occupations such as photographers, network anchors, etc., with cyclical tourism needs of the crowd, including the existence of long-term cooperation in the marketing department. The fixed passenger flow generated by the source organization unit, such as: cooperation with the education department of the source area, the use of students ' winter and summer vacations, the ' study tour ' dedicated train, the 'team building' and the theme dedicated train in cooperation with enterprises and institutions. Generally, the higher the economic level and population base of the source area, the higher the trend passenger flow affected by tourism demand, which is a gradual growth relationship.

(2) Induced passenger flow

The induced passenger flow is attracted by the railway passenger transport department after the publicity of the dedicated train products. The process of attracting passenger flow is a gradual dynamic process. The railway transportation department improves the quality of the dedicated train products, such as economy, professionalism, comfort, transportation capacity, experience, customization, new tourism route development, etc., as well as the implementation of the new line plan and the adjustment of the new line plan, so that some people who are not willing to travel are willing to choose to travel on the dedicated train, that is, the potential tourism demand of these people is activated, thus bringing passenger flow to the dedicated train. This process has step fluctuation characteristics.

(3) Transferred passenger flow

This passenger flow is attracted by the tourism mode and service of the tourist-dedicated train after the opening of the tourist-dedicated train. It can choose other modes of transportation or tourism, but instead choose the tourist-dedicated train. Transfer passenger flow is the passenger flow attracted by the railway transportation department after competing with other tourism organizations in the market competition by improving its own product strength. The generation of this passenger flow is related to the competitiveness of other tourism and transportation modes. It lies in the change of the sharing rate of tourism passenger flow in the system, which is uncertain.

4 BASIC PRINCIPLES OF SYSTEM DYNAMICS AND TOURIST-DEDICATED TRAIN PASSENGER FLOW FORECASTING BASED ON SYSTEM DYNAMICS

4.1 Brief Introduction of System Dynamics

The operation system of tourist-dedicated train is a typical social and economic system, and the passenger flow analysis system, as a part of the operation system of tourist-dedicated train is also a part of the social and economic system of tourist-dedicated train.

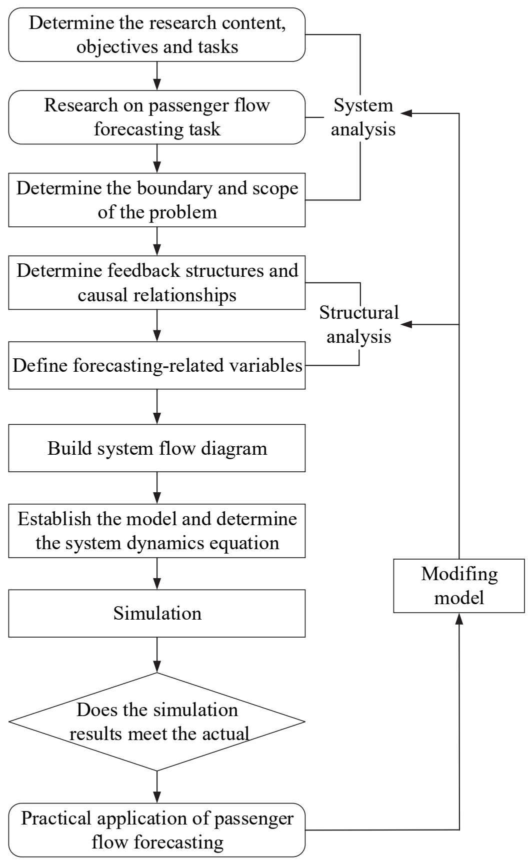

Figure 1 The workflow of the system dynamics model of tourist-dedicated train passenger flow forecasting

The system dynamics model can be used to set multi-mode scenarios of different factor combinations to forecast and analyze the demand of tourist-dedicated trains, which is an applicable method for demand forecasting of complex systems. Starting from the internal and external system mechanism of tourist-dedicated train passenger flow, the causal relationship between population, economy, facility investment, civil aviation and other factors related to the formation of passenger flow is analyzed, and the forecasting model of passenger flow based on system dynamics is constructed. The specific system workflow is shown in Fig. 1.

4.2 Tourist-dedicated Train Passenger Flow Forecasting Based on System Dynamics

The purpose of this chapter aims to analyze the mechanism and related influencing factors of the formation and evolution of the passenger flow of the tourist-dedicated train; the system dynamics forecasting model of the corresponding passenger flow forecasting is established, and a variety of scenarios are set up to reasonably forecast the change of passenger flow.

4.2.1 Analysis of Influencing Factors of Tourist-dedicated Train Passenger Flow

This section selects the forecast of tourist-dedicated train passenger flow as the research object. Before constructing the system dynamics model, according to the existing research [14-25], combined with the characteristics of the passenger flow of the dicated train, the key influencing factors of the passenger flow of the dedicated train passenger flow are extracted from many possible factors. The causal loop diagram between the elements is constructed, and the positive and negative feedback loops of the loop diagram are analyzed, and the corresponding dynamic hypothesis is proposed. The key influencing factors are analyzed as follows:

(1) Population quantity.

Tourism activities are completed by people. The number of population as the base determines the number of tourism demand. The number of regional population is a general number. In addition, the number of regional population is a crucial part of many transportation systems. In many sustainable development models, the dynamic influence of population factors must be considered. The development of population changes directly affects the choice of transportation modes and the change of transportation quantity. In the construction of forecasting system, population is an important system variable and an indispensable influencing factor in demand forecasting research.

(2) Economic conditions of source areas.

Passenger demand is a reflection of passenger travel demand and an important reflection of the vitality of national economic and social activities. Passenger demand is greatly affected by economic and social factors, among which a good economic environment has created a large number of travel demands. For tourist flow, the higher the economic level of the tourist source area, the more likely it is to generate tourist flow, and the higher the proportion of railway tourism in passenger flow.

(3) GDP per capita factor.

Per capita GDP is the basis of personal consumption ability and the reflection of tourism consumption ability. Usually, per capita GDP is proportional to personal disposable income. The growth of per capita GDP level will bring about the improvement of living standards, thus stimulating individual demand for leisure activities such as tourism. This in turn leads to an increase in travel behavior. Per capita GDP is also an important background for the upgrading of tourism consumption level. The higher the per capita GDP, the higher the potential tourism demand.

(4) Train line plan and timetable.

The dedicated train line plan includes the stop plan and the number of dedicated trains. It is an important factor in the supply of dedicated train services and a supply side that meets the balance between supply and demand of passenger flow. The dedicated train timetable is a time-based product for passengers ' travel choices. Through reading it, passengers can obtain travel information and stimulate travel demand.

(5) Competition of other modes of transport.

The tourism traffic mode of the dedicated train is mainly aimed at the medium and long distance. Within this distance range, high-speed rail, aviation and so on, as the representative of fast and comfortable travel mode, have a strong attraction in the medium and long distance travel. In terms of scale, in the future, civil aviation and high-speed rail will continue to form a competitive pattern for tourism trains. Some airlines also attract tourists by setting up travel agencies or forming transportation-tourism associations with other travel agencies. These competitions have an impact on tourists' travel behavior, which in turn affects the formation of passenger demand for dedicated trains.

(6) Competition from other forms of tourism.

The dedicated train can replace the physical hotel and avoid the hardship of passengers carrying luggage back and forth. However, in terms of comfort, there is still a certain gap between the dedicated train and the physical hotel, and the two constitute a competitive advantage. There is competition in the choice of tourists' travel behavior between the dedicated train travel mode and the 'free travel', self-driving travel and other travel modes. Therefore, it is of great significance to study how to learn from each other to improve the satisfaction of special train passenger flow and improve the competition between dedicated train and other tourism modes to promote the growth of passenger flow.

(7) Tourist-dedicated train supply factors.

The supply of tourism trains is an important supply-side factor of rail passenger demand, including displacement supply and service supply. The displacement supply refers to the supply of transportation services provided by the dedicated trains, including the number of dedicated trains that can be operated, the number of available locomotives, and the station capacity. It also includes the railway passenger transport mileage, the coverage of the railway station to the scenic areas, the accessibility level of the dedicated trains, and the distribution capacity of the station connection. Generally, the longer the passenger mileage, the higher the coverage rate, the accessibility level and the station connection distribution, the more conducive to the development of the dedicated train line, so that there are more options available to tourists, the more conducive to attracting more tourists to use the dedicated train for tourism activities. The service supply refers to the services exported by the passenger transport department, including passenger transport services such as midway train accommodation and catering, and tourist-dedicated train tourism services such as guided tours, commodity and souvenir sales, and performances. These services are unique to the dedicated train and do not have other modes of transportation. They have certain attraction to tourists. The richer the supply and the higher the service quality, the more conducive they are to attracting more tourists.

(8) Income of tourist-dedicated trains.

The income of the dedicated train is a reflection of the operation efficiency and passenger flow level of the dedicated train. It is the guarantee to maintaining the competitiveness of the dedicated train project in the tourism market, and it also has a certain impact on attracting passenger flow and maintaining stable passenger flow.

(9) Tourist-dedicated train ticket price.

In the formulation of the ticket price of the dedicated train for tourism, it is necessary to consider the service level provided and the product attributes of the dedicated train as a tourism product, which is not a simple displacement pricing. Pricing directly affects tourists' travel behavior choice and travel experience. Reasonable pricing, usually through careful market research, helps to attract passenger flow and improve the competitiveness of dedicated train products.

(10) Tourist-dedicated train hardware facilities.

The hardware facilities of the dedicated train include the environmental layout of the soft sleeper cabin, the dining cabin, and the functional theme cabin. The degree of facility improvement is very important for the passenger's halfway experience, and it is also an important indicator to attract passenger flow.

(11) Dedicated train service level.

The service level of dedicated trains refers to the comprehensive and detailed service of passenger transport service level and tourism service level, which helps to improve passenger satisfaction and attract passenger flow.

(12) Profit input ratio.

The proportion of the profit part used to expand the operation scale or improve the operation level after deducting the operation cost from the income obtained by the dedicated train operation department. If the input ratio is too low, the transportation capacity cannot be improved, and too high will cause waste of resources.

(13) Tourism attraction factors.

Tourism environmental conditions are one of the important factors to attract tourists. The primary consideration of the running of the dedicated train includes the influence scope of the scenic spots covered by the line and the degree of attraction of the scenic spots to the tourists. Whether the tourism environment is attractive to the dedicated train tourists needs to be considered from many aspects, such as the level and classification of the scenic areas, the local propaganda of the scenic spot, the policy support and so on.

4.2.2 Analysis of Causality

The relationship between the factors in the system is relatively complex. In order to clarify the relationship between the factors, it is a necessary step to draw a causal loop diagram, in order to qualitatively express the relationship. The tourist-dedicated train's causal loop diagram passenger flow forecasting system is shown in Fig. 2.

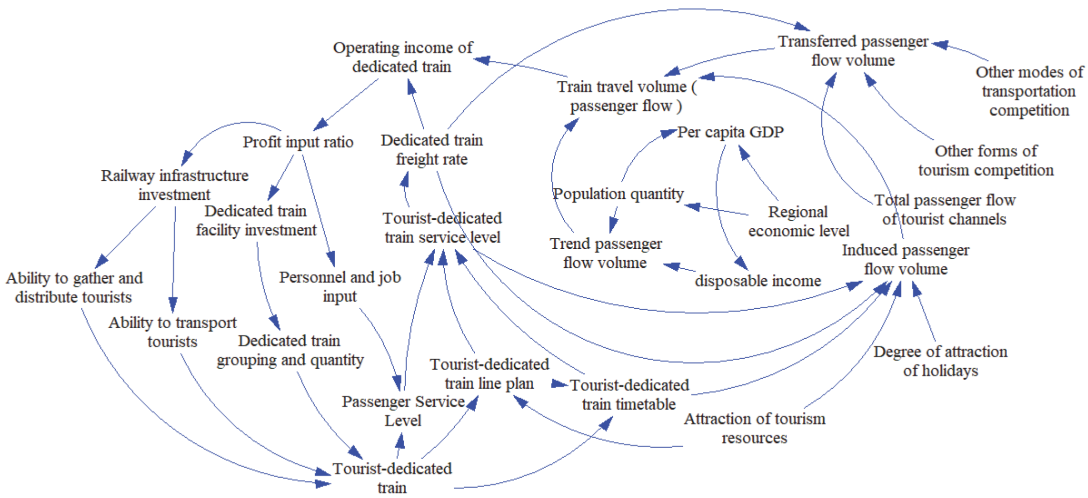

Figure 2 The causal loop diagram of the passenger flow of the tourist-dedicated train

The feedback relationship between various factors in the system is complex, and the causal loop diagram is sorted out. By combing through the diagram, eleven causal feedback loops can be obtained, of which eight main causal feedback loops are as follows:

Feedback loop 1: Dedicated train income→ + Profit input ratio→+Railway infrastructure investment→+Ability to gather and distribute tourists→+ Tourist-dedicated train supply→+ Passenger Service Level→+ Tourist-dedicated train service level→+ Dedicated train freight rate→+ Dedicated train income.

This loop is a positive feedback loop, reflecting the impact of train operation income and infrastructure investment on dedicated train travel supply and dedicated train service level.

Feedback loop 2: Dedicated train income→ + Profit input ratio→ + Dedicated train facility investment→ + Dedicated train grouping and quantity→ + Passenger Service Level→ + Tourist-dedicated train service level→ + Dedicated train freight rate→ + Dedicated train income.

This loop is a positive feedback loop, reflecting the causal feedback relationship between the train vehicle support capability and the service level in the dedicated train supply.

Feedback loop 3: Dedicated train income→ + Profit input ratio→ + Personnel and job input→ + Passenger Service Level→ + Tourist-dedicated train service level→ + Dedicated train freight rate→ + Dedicated train income.

This loop is a positive feedback loop, reflecting the causal feedback relationship between personnel post input and passenger service level and dedicated train income.

Feedback loop 4: Dedicated train passenger flow volume→ + Profit input ratio→ + Dedicated train facility investment→ + Dedicated train grouping and quantity→ + Tourist-dedicated train supply→ + Passenger Service Level→ + Tourist-dedicated train service level→ + Induced passenger flow volume→ + Dedicated train passenger flow volume.

This loop is a positive feedback loop, reflecting the impact of the investment level of the dedicated train facilities on the induced passenger flow.

Feedback loop 5: Dedicated train passenger flow volume→ + Profit input ratio→ + Railway infrastructure investment→ + Ability to gather and distribute and transport tourists→ + Tourist-dedicated train supply→ + Passenger Service Level→ + Tourist-dedicated train service level→ + Induced passenger flow volume→ + Dedicated train passenger flow volume.

This loop is a positive feedback loop, and the impact of railway infrastructure investment on passenger service level and induced passenger flow.

Feedback loop 6: Dedicated train passenger flow volume→ + Dedicated train income→ + Profit input ratio→ + Personnel and job input→ + Passenger Service Level→ + Tourist-dedicated train service level→ + Induced passenger flow volume→ + Dedicated train passenger flow volume.

This loop is a positive feedback loop, reflecting the causal feedback relationship between the operating income of the dedicated train, the input of personnel positions, and the freight rate of the dedicated train and the induced passenger flow.

Feedback loop 7: Dedicated train passenger flow volume→ + Dedicated train income→ + Profit input ratio→ + Related Investments→ + Passenger Service Level→ + Tourist-dedicated train service level→ + Dedicated train freight rate→-Induced passenger flow volume→ + Dedicated train passenger flow volume.

This loop is a negative feedback loop. The feedback loop shows that the higher the dedicated train freight rate, the easier it is to reduce the potential travel demand, reduce the induced passenger flow, and thus affect the passenger flow.

Feedback loop 8: Tourist-dedicated train service level→ + Induced passenger flow volume→ + Dedicated train passenger flow volume→ + Dedicated train income→ + Related Investments→ + Travel supply→ + Passenger Service Level→ + Tourist-dedicated train service level

This loop is a positive feedback loop, reflecting the causal feedback relationship between travel supply, train service level and induced passenger flow, dedicated train passenger flow and dedicated train income, and investment supply.

4.2.3 System Flow Diagram Analysis

According to the above causal feedback relationship, the main feedback loops are combined to obtain the flow chart of the tourist-dedicated train passenger flow forecasting system, as shown in Fig. 3.

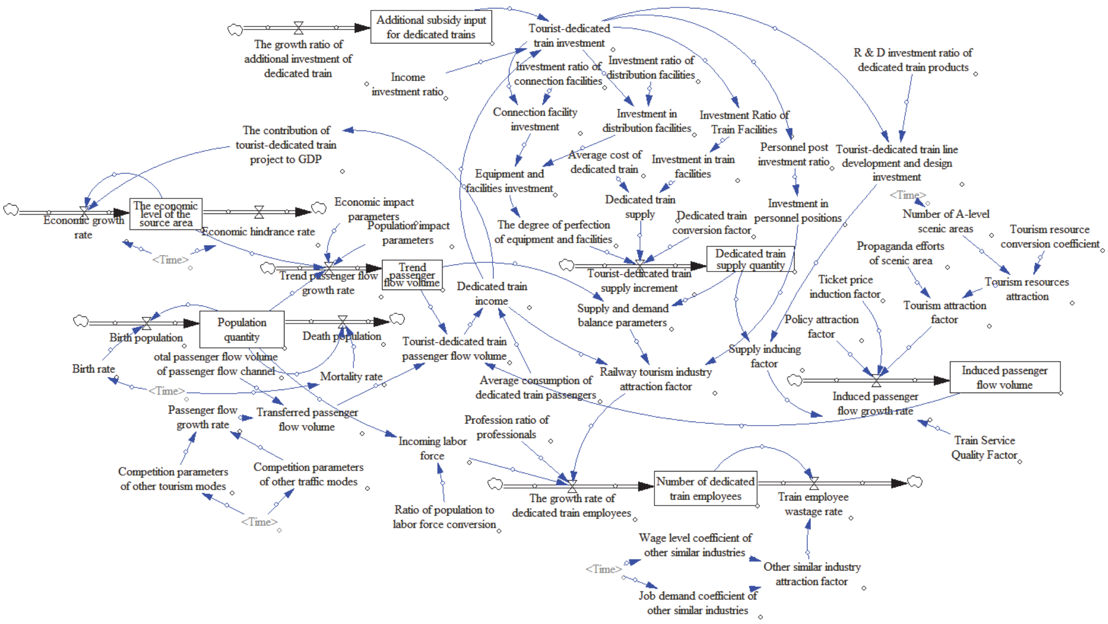

Figure 3 Flow chart of tourist-dedicated train passenger flow forecasting system

4.2.4 Model Establishment and Test

Considering the influence of many factors on passenger flow forecasting, the following assumptions are made before constructing the system dynamics model:

(1) Assuming that the irresistible factors of tourism passenger flow will not appear in the simulation period, the system model is continuous, and each variable is within the effective control range, such as public health events that affect major government policy changes in tourism and railway transportation, epidemics, etc.

(2) Assume that the external environment of the system

model has a very small impact on the internal system, which can be ignored.
(3) There is a certain regularity in the rate of change of factors such as the wage level of the tourism industry, the per capita consumption of tourism, and the number of scenic spots, that is, the trend of convergence with the historical rate of change.
(4) The dynamic cycle process of the system will not change the nature of the internal elements of each subsystem. The change of the parameters of the relevant elements in the system can have an impact on the prediction of the passenger flow of the dedicated train, that is, the future development trend.
According to the system flow diagram structure, the system dynamics model is constructed by combining the key variable analysis and other available data. The main DYNAMO model equations are as follows:
(1) INITIAL YEAR = 2008
(2) FINAL YEAR = 2035
(3) SAVEPER = TIME STEP, Units: Year
(4) TIME STEP = 1, Units: Year
(5) Population quantity = INTEG (Birth population – Death population, Initial value)
(6) Birth population = Population quantity × Birth rate, Units: Ten thousand people / year
(7) Death population = Population quantity × Mortality rate, Units: Ten thousand people / year
(8) Birth rate = WITH LOOKUP (Table function, Time), Units: Dmnl / year
(9) Mortality rate = WITH LOOKUP (Table function, Time), Units: Dmnl / year
(10) Dedicated train income = Tourist-dedicated train passenger flow volume × Average consumption of dedicated train passengers, Units: Ten thousand yuan
(11) The contribution of tourist-dedicated train project to GDP = Dedicated train income / Regional secondary and tertiary GDP
(12) Regional secondary and tertiary GDP = WITH LOOKUP (Table function, Time), Units: 100 millon yuan / year
(13) Tourist-dedicated train investment = Dedicated train income × Income investment ratio + Additional subsidy input for dedicated trains, Units: Ten thousand yuan / year
(14) Tourist-dedicated train investment = Equipment and facilities investment + Investment in train facilities + Tourist-dedicated train line development and design investment, Units: Ten thousand yuan / year
(15) The economic level of the source area = INTEG (Economic growth rate – Economic hindrance rate, Initial value), Units: Dmnl
(16) Economic growth rate = WITH LOOKUP (Table Function, Time), Units: Dmnl
(17) Economic hindrance rate = WITH LOOKUP (Table Function, Time), Units: Dmnl
(18) Equipment and facilities investment = Investment in distribution facilities Units: Ten thousand people / year
(19) Investment in train facilities = Personnel post investment ratio × Tourist-dedicated train investment, Units: Ten thousand yuan / year
(20) Connection facility investment = Investment ratio of distribution facilities × Tourist-dedicated train investment, Units: Ten thousand yuan / year
(21) Investment in distribution facilities = Investment Ratio of Train Facilities × Tourist-dedicated train investment, Units: Ten thousand yuan / year
(22) Tourist-dedicated train line development and design investmen = R & D investment ratio of dedicated train products × Tourist-dedicated train investment, Units: Ten thousand yuan / year
(23) Supply and demand balance coefficient = Tourist-dedicated train supply quantity / Trend passenger flow volume, Units: Dmnl
(24) Investment in personnel positions = Tourist-dedicated train investment × Personnel post investment ratio, Units: Ten thousand yuan / year
(25) Investment ratio of equipment and facilities + Personnel post investment ratio + R & D investment ratio of dedicated train products = 1
(26) Additional subsidy input for dedicated trains = Additional subsidy input for dedicated trains × The growth ratio of additional investment of dedicated train, Units: Ten thousand yuan / year
(27) Dedicated train income = Average consumption of dedicated train passengers × Tourist-dedicated train passenger flow volume, Units: Ten thousand people / year
(28) Dedicated train supply = Investment in train facilities / Average cost of dedicated train, Units: Train
(29) Tourist-dedicated train supply quantity = INTEG (Tourist-dedicated train supply increment, Initial value), Units: Train
(30) Tourist-dedicated train supply increment = The degree of perfection of equipment and facilities + Dedicated train supply × Dedicated train conversion factor, Units: Train
(31) Number of dedicated train employees = INTEG (The growth rate of dedicated train employees – Train employee wastage rate, Initial value), Units: Ten thousand people
(32) The growth rate of dedicated train employees = Incoming labor force × Dedicated train personnel employment ratio, Units: Ten thousand people
(33) Incoming labor force = Population quantity × Ratio of population to labor force conversion, Units: Ten thousand people
(34) Train employee wastage rate = Number of dedicated train employees × Other similar industry attraction factor, Units: Dmnl
(35) Other similar industry attraction factor = Job demand coefficient of other similar industries + Wage level coefficient of other similar industries, Units: Dmnl
(36) Job demand coefficient of other similar industries = WITH LOOKUP (Table Function, Time), Units: Dmnl
(37) Wage level coefficient of other similar industries = Wage levels in other similar industries × Wage coefficient conversion rate Units: Dmnl
(38) Wage levels in other similar industries = WITH LOOKUP (Table Function, Time), Units: Ten thousand yuan / year
(39) Trend passenger flow volume = INTEG (Trend passenger flow growth rate), Units: Ten thousand people
(40) Trend passenger flow growth rate = The economic level of tourist source area × Economic impact parameters + Population quantity × Population impact parameters, Units: Dmnl
(41) Policy attraction factor = Tourism attraction policy × Attraction coefficient, Units: Dmnl
(42) Ticket price induction factor = (Idea ticket price – Actual ticket price) × conversion coefficient, Units: Dmnl

(43) Tourism attraction factor = Tourism attraction coefficient × Number of A-level scenic areas + Propaganda efforts of scenic area, Units: Ten thousand people
(44) Number of A-level scenic areas = WITH LOOKUP (Table function, Time), Units: area
(45) Propaganda efforts of scenic areas = WITH LOOKUP (Table function, Time), Units: Dmnl
(46) Transferred passenger flow volume = Total passenger flow volume of passenger flow channel × Transferred passenger flow growth rate, Units: Ten thousand people
(47) Transferred passenger flow growth rate = Competition coefficient of other tourism traffic modes + Competition coefficient of other tourism modes, Units: Ten thousand people
(48) Induced passenger flow volume = INTEG (Induced passenger flow growth rate, Initial value), Units: Ten thousand people
(49) Induced passenger flow growth rate = Tourism attraction factor + Policy attraction factor + Supply inducing factor + Ticket price induction factor
(50) Tourism resources attraction = Number of A-level scenic areas × Tourism resource conversion coefficient
(51) Policy attraction factor = WITH LOOKUP (Table Function, Time), Units: Ten thousand people
(52) Supply inducing factor = Tourist-dedicated train supply quantity × The influence factor of the supply of the dedicated train on the total supply + Tourist-dedicated train line development and design investment × The impact factor of dedicated train development on total supply, Units: Dmnl
(53) Other modes of transportation competition factor = lookup (Time, Table Function), Units: Dmnl
(54) Other forms of tourism competition factor = lookup (Time, Table Function), Units: Dmnl
(55) Tourist-dedicated train passenger flow volume = Trend passenger flow volume + Induced passenger flow volume + Transferred passenger flow volume, Units: Ten thousand people
The dimension and boundary test of the model, the model logic test, and the validity test compared with the traditional forecasting method can determine that the model in this paper meets the theoretical requirements.

5 ANALYSIS OF EXAMPLES

5.1 Example Background

The model is verified by a small-scale example and a large-scale example. The simulation forecasting time step of the example is 1 year. Considering the influence of factors such as the COVID-19 from 2019 to 2022, it is a special case that does not have the general forecasting law, and the relevant data during this period is not used as the reference source of the forecasting data. The dynamic model in the example is simulated and verified by Vensim PLE 7.3.5. The main data sources of the system dynamics model are data published by data sources such as China National Statistical Yearbook, industry data, and China Railway Statistical Yearbook

5.2 Example

5.2.1 Small-scale example

Taking the passenger flow forecasting problem of the tourist-dedicated train project of Lanzhou Railway Bureau Group Company of China as a small-scale example, the source areas include Lanzhou-Xining Northwest Urban Circle, Lanzhou-Xi'an Northwest Urban Circle, Lanzhou-Yinchuan Northwest Urban Circle. The relevant data from 2014 to 2017 are selected for testing. Among them, 2014 is the first year of the benchmark, and the time step is set to 1 year. The results are compared with the prediction results of grey GM (1, 1) model, linear regression model and neural network. All of the three are classical prediction theories, in which the grey GM (1, 1) model is the mean form differential GM (1, 1) model, the regression model adopts the polynomial linear regression model, and the neural network adopts the generalized regression neural network (GRNN). The relevant parameters of the system dynamics model are set as follows:
The index of economic related factors in the system flow chart is quantified by the total GDP of the tertiary industry. From 2014 to 2019, the GDP growth rate of the secondary and tertiary industries is 3% - 4.5%, and the economic hindrance rate is 0.13% - 0.65%, and the forecast period is unchanged. There are 74 scenic spots above 4A covered by Lanzhou Railway Bureau Tourism Train. In terms of demographic factors, the birth rate of Gansu Province, the main tourist source of the special train, ranges from 7.65‰ to 8.83‰, the mortality rate ranges from 8.23‰ to 9.12‰, the population growth rate ranges from –0.67‰ to –0.29‰, the population labor conversion ratio is 49% to 72%, and the employment ratio of the dedicated train personnel is 0.0068. The investment ratio of tourist-dedicated train income is 0.13, the investment ratio of connecting facilities is 0.23, the investment ratio of distribution facilities is 0.23, the investment ratio of dedicated train facilities is 0.21, the investment ratio of personnel positions is 0.08, and the investment ratio of dedicated train product development is 0.12. The additional investment growth ratio of the dedicated train is 0.14. In terms of the cost of tourist-dedicated trains, the cost of different theme carriages is different. Usually, the cost of upgrading and reconstruction of single carriages is 1.9 million yuan, and new cars are purchased directly. The unit price of single carriages is between 3.5 million and 4 million yuan. In the example, it is assumed that 12 new carriages are purchased every year to form 1.5 trains of dedicated trains and 18 cars are transformed. The wage level coefficient of other similar industries is 0.075, the job demand coefficient of other similar industries is 0.029, the value range of competition parameters of other tourism modes is –0.21 ~ 0.09, the value range of competition parameters of other tourism transportation modes is –0.17 ~ 0.45, the employment ratio of dedicated train personnel is 4/106, the value of economic impact parameter is 0.0017, the value of population impact parameter is 0.00083, the value range of tourism supply factor is 0 ~ 0.0036, and the value range of tourism induction factor is 0.0013 ~ 0.0044. The value range of fare induction factor is 0 ~ 0.0092, the value range of policy attraction factor is 0 ~ 0.0069, and the value range of dedicated train service quality factor is 0 ~ 0.0042. The forecasting results and error data calculated by the system dynamics model and the three comparison model forecasting methods are shown in Tab. 1. The relative error in the table is the percentage of the absolute value of the

difference between the actual value and the predicted value of each forecasting model to the actual value. Three indicators are used to predict and evaluate different prediction results. In addition to the relative error percentage, the evaluation index also uses three indicators widely used in three transportation fields, namely, the average absolute error *MAE*, the absolute percentage error *MAPE*, and the root mean square error *RMSE*. The calculation formula of the three is as shown in Eq. (1) to Eq. (3):

$$MAE\left(r,\, r'\right)=\frac{1}{n}\sum_{i=1}^{n}\left|r_i-r_i'\right| \tag{1}$$

$$MAPE\left(r,\, r'\right)=\frac{1}{n}\sum_{i=1}^{n}\left|\frac{r_i-r_i'}{r_i}\right| \tag{2}$$

$$RMSE\left(r,\, r'\right)=\sqrt{\frac{1}{n}\sum_{i=1}^{n}\left(r_i-r_i'\right)^2} \tag{3}$$

where: r_i and r_i' represent the true value and the forecasted value of the ith time step, respectively.

The forecasting results of the four forecasting models are shown in Tab. 1. The error indicators calculation results of the four forecasting methods are shown in Tab. 2.

Table 1 The forecasting results of the four forecasting models

Characteristics years	Actual value (million people)	Grey GM (1,1) model		Linear regression model		Neural network model		System dynamics model	
		Forecasting value / million people	Relative error / %	Forecasting value / million people	Relative error / %	Forecasting value / million people	Relative error / %	Forecasting value / million people	Relative error / %
2008	0.1794	0.1813	1.06	0.2119	18.12	0.1893	5.52	0.1627	9.31
2009	0.2988	0.3025	1.24	0.199	33.4	0.2706	9.44	0.2675	10.48
2010	0.3772	0.3928	4.14	0.2843	24.63	0.3342	1.40	0.4009	6.28
2011	0.4454	0.4636	4.09	0.4678	5.03	0.4015	9.86	0.4428	0.58
2012	0.6346	0.5775	9.25	0.7495	18.11	0.5963	6.04	0.5924	6.65
2013	0.903	0.8194	9.26	1.1294	25.07	0.8432	6.62	0.8556	5.25
2014	1.574	0.9961	3.672	1.6075	2.13	1.3792	12.38	1.842	17.03
2015	2.039	1.9162	6.02	2.1838	7.1	2.4453	19.93	2.427	19.03
2016	3.215	2.7904	13.21	2.8583	11.09	3.3459	4.07	3.288	2.27
2017	3.993	3.732	6.54	3.631	9.07	4.4527	11.51	4.2017	5.23

Table 2 The error index values of each forecasting model of small-scale example

	Grey GM (1, 1) model	Linear regression model	Neural network model	System dynamics model
Mean error percentage	10.34%	15.38%	9.68%	8.22%
MAE	0.1683	0.1486	0.1415	0.1102
MAPE	0.1034	0.1537	0.9676	0.0821
RMSE	0.2652	0.1910	0.2100	0.1665

According to Tab. 2, it can be seen that between the characteristic years 2008 - 2017, the error indicators of the four forecasting models are shown in the table. Among them, the error performance of the system dynamics model is the best, and the average error fluctuation is also the smallest, which has certain credibility. The system dynamics model is used to predict the passenger flow of the tourism special train in Lanzhou Bureau from 2024 to 2030. The prediction results of passenger flow are shown in Tab. 3, and the trend is shown in Fig. 4.

Table 3 Forecasting results of passenger flow in Lanzhou Railway Bureau from 2023 to 2030

Forecast year	2024	2025	2026	2027	2028	2029	2030
Forecast passenger flow / million people	5.447	6.811	7.254	7.983	8.645	9.657	10.158

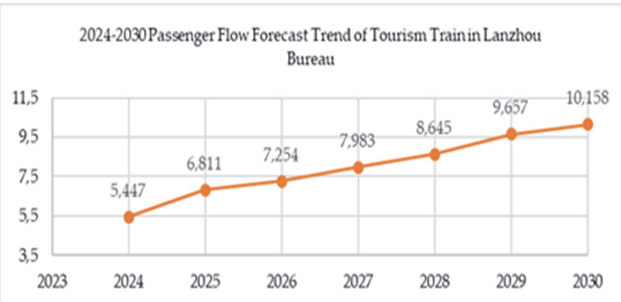

Figure 4 The development trend of passenger flow forecast of tourism special train in Lanzhou Bureau from 2024 to 2030

5.2.2 Large Scale Example

The large scale example takes the passenger flow forecast of china railway tourist-dedicated train as an example to simulate the passenger flow forecast under different circumstances. First of all, the data from 2008 to 2017 are historical experience data to verify the forecasting system. Since 2014, the number of running dedicated trains and the number of passengers sent by China Railway are shown in Fig. 5 and Fig. 6. Taking 2008 as the starting point of method validation, the simulation time step ΔT is 1 year. On the basis of the verification results, the forecast of 2023 - 2035 is carried out, and 13 years are set as the simulation time cycle, and the simulation time step ΔT is also 1 year. The main data sources of the system dynamics model are data published by data sources such as China National Statistical Yearbook, industry data and China Railway Statistical Yearbook.

Based on the historical statistics and the analysis of the "National Population Development Plan (2016 - 2030)" report, it can be found that in recent years, China's population growth is still at a low level. Due to the influence of factors such as the change of fertility concept, the probability of population growth rate remaining low for a long time is high. At the same time, with the upgrading of medical technology, the mortality rate decreased. In terms of total population, the aging of the population is rising, and the total population will grow at a low and slow rate for a long time. Based on this, it is estimated that the birth rate from 2022 to 2025 will be between 6.5‰ and 10‰, the mortality rate will be between 7‰ and 8‰, and the natural population growth rate will be between 0.3‰ and 1.7‰. In terms of economic factors, in recent years, due to the complex changes in the international environment, China 's overall economic level has slowed down, but it still maintains a steady growth trend at a medium-low speed, and the characteristics of sustainable growth are obvious.

Figure 5 Changes in the number of China's railway tourist-dedicated trains in recent

Figure 6 Changes in the number of passengers transported by China's railway tourist-dedicated trains in recent years

The two industrial components of the tourist-dedicated train operation: the railway transportation industry and the tourism industry belong to the tertiary industry. Therefore, the economic related factors in the system flow diagram are quantified by the total GDP of the tertiary industry. Based on this, it is estimated that the GDP growth rate of the secondary and tertiary industries in the country will be 2.3% ~ 5% from 2020 to 2035. The number of 4A scenic areas in China is 1284, and the number of 5A scenic areas is 318, with a total of 1602. Through investigation, it is considered that there are about 1080 scenic areas above 4A that can be covered by the tourist-dedicated train service. At present, the dedicated train service coverage is about 13.42%. In recent years, the total number of labor force in China has shown a downward trend since 2016. The labor force conversion rate of the population is 59% ~ 75%, and the employment ratio of dedicated train personnel is 0.007 ~ 0.009. The investment ratio of tourist-dedicated train is 0.1, the investment ratio of connection facilities is 0.25, the investment ratio of distribution facilities is 0.15, the investment ratio of dedicated train facilities is 0.25, the investment ratio of personnel positions is 0.11, and the investment ratio of dedicated train product development is 0.14. Due to the wide application of high-speed rail trains, ordinary passenger trains are largely idled. It is a good measure for railway transportation enterprises to transform them into tourist-dedicated trains. In terms of the cost of dedicated trains, the cost of different theme carriages is different. Usually, the cost of upgrading and reconstruction of single carriages is between 1.7 million yuan and 2.3 million yuan. If new cars are purchased directly, the unit price of single carriages is between 3.5 million and 4 million yuan. The whole train takes 12-column marshalling as an example, including 10 functional theme cabins, 1 camping cabin and 1 power generation cabin. The overall upgrading needs about 20 million yuan. The passenger consumption of the tourist-dedicated train includes the consumption of the dedicated train tickets and the consumption during the dedicated train tour. The more places the dedicated train tours are, the longer the travel time is, and the higher the passenger's consumption in the dedicated train. If the average consumption level is based on yuan / day, according to the statistical data, the per capita consumption of the dedicated train passengers is mostly concentrated in 450 ~ 700 yuan / day. If the unit is based on yuan / km, it is about 0.26 ~ 0.47 yuan / km. The wage level coefficient of other similar industries is 0.074, the demand coefficient of other similar industries is 0.027, the value range of competition parameters of other tourism modes is –0.25 ~ 0.13, the value range of competition parameters of other tourism transportation modes is –0.37 ~ 0.15, the employment ratio of dedicated train personnel is $4/10^6$, the value of economic impact parameters is 0.0017, the value of population impact parameters is 0.00083, the value range of tourism supply factors is 0 ~ 0.0036, and the value range of tourism induction factors is 0.0013 ~ 0.0044. The value range of fare induction factor is 0 ~ 0.0092, the value range of policy attraction factor is 0 ~ 0.0069, and the value range of dedicated train service quality factor is 0 ~ 0.0042. In the process of setting situational parameters, considering China's current economic development and population level, the future development trend is forecasted, and the value of situational parameters is determined on this basis. At present, China's economic growth is in a smooth transition stage from high-speed growth to medium-speed stable growth, with outstanding sustainability characteristics; the population growth rate has declined significantly, or will be in a low-speed growth range for a long time. Based on this, the passenger flow forecasting in three situations is simulated, and the three situations are reflected by different situational parameters. Based on this, the passenger flow forecasting in three situations is simulated, and the three situations are reflected by different situational parameters. As a part of the economic system, the passenger flow forecasting system is affected by economic growth, population change, and dedicated train input variables. The three are independent and related to each other. The connection between them is that economic factors are also the main reasons affecting population factors and dedicated train input factors. In general, the better the economic environment is, the more conducive it is to the growth of dedicated train passenger flow. The setting of situational parameters can be set according to the high, medium and low speed development models, and the values are shown in Tab. 4. The relevant data from 2008 to 2017 are selected for testing, and the four methods are forecasted as shown in Tab. 5. Similarly, the calculation of each error indicators is shown in Tab. 6.

Table 4 Values of situational parameters under three development modes

	High-speed development model	Medium-speed development model	Low-speed development model
GDP growth rate	5.3%	2.7%	1.44%
Rate of population growth	5.73‰	2.47‰	1.75‰
The growth ratio of additional investment of dedicated train	12%	7%	3%
Income investment ratio	13.6%	8.52%	4.7%

Table 5 Example passenger flow model forecasting results and errors

Characteristic year	Actual value / Ten thousand people	Grey GM (1, 1) mode		Linear regression model		Neural network model		System dynamics model	
		Forecasting value	Relative error / %	Forecasting value	Relative erro / %	Forecasting value	Relative erro / %	Forecasting value	Relative erro / %
2008	72.9	65.92	9.57	85.57	17.38	77.38	06.15	79.5	9.05
2009	81.8	77.83	4.85	87.19	6.59	88.23	07.86	82.7	1.1
2010	84	82.29	2.04	90.08	7.24	93.15	10.89	87.5	4.17
2011	89.4	86.26	3.51	94.23	5.4	97.28	8.81	95	6.26
2012	96.5	88.58	8.21	99.64	3.25	104.23	8.01	99	2.59
2013	100	93.41	6.59	106.32	6.32	106.25	6.25	104.9	4.9
2014	107	95.92	10.36	114.26	6.79	111.32	4.04	98	8.41
2015	111	101.15	8.87	123.47	11.23	116.55	5.00	102	8.11
2016	130	106.66	17.95	133.94	3.03	123.28	5.17	122	6.15
2017	146	114.53	21.55	145.67	0.23	137.56	5.78	139	4.79

Table 6 The error index values of each forecasting model of large-scale example

	Grey GM (1, 1) model	Linear regression model	Neural network model	System dynamics model
Mean error percentage	9.35%	6.76%	6.796%	5.55%
MAE	10.6050	6.2430	6.6950	5.7000
MAPE	0.09351	0.0675	0.0679	0.0555
RMSE	13.9218	7.2359	6.8953	6.2709

According to Tab. 2, it can be seen that between the characteristic years 2014 - 2017.The error percentage of the system dynamics model is still the lowest, and the error fluctuation is also relatively the smallest, that is, through the comparison of real historical data, objectively verify the effect of application of the system dynamics model. Under the three scenarios set in Tab. 1, the system dynamics model is used to further forecast the national railway tourism passenger flow from 2023 to 2035, and forecasting results under the three modes are obtained as shown in Fig. 7.

Through the model forecasting results, it can be seen that the future tourist-dedicated train passenger flow will show a slow upward trend. If it is carried out according to the low-speed development model, it will reach 1 million passengers in 2028. If it is carried out according to the high-speed development model, it will reach 1.7 million passengers in 2034. In order to test the sensitivity of the model to the development situation parameters, the influence of parameter changes on passenger flow can be observed by adjusting the parameters in. Firstly, in the low-speed development model, the extra investment growth ratio of the special train is adjusted from 3% to –0.5% while maintaining the economic and population growth trend unchanged. The passenger flow forecast results are shown in Fig. 8.

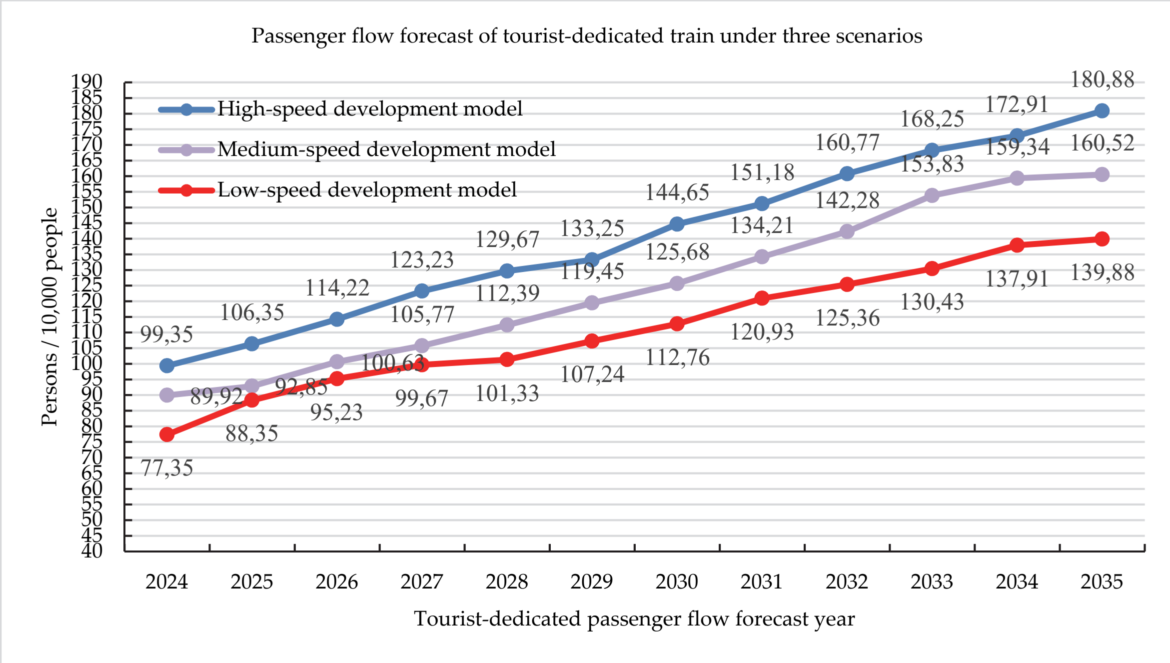

Figure 7 Passenger flow forecast of tourist-dedicated train under three scenarios

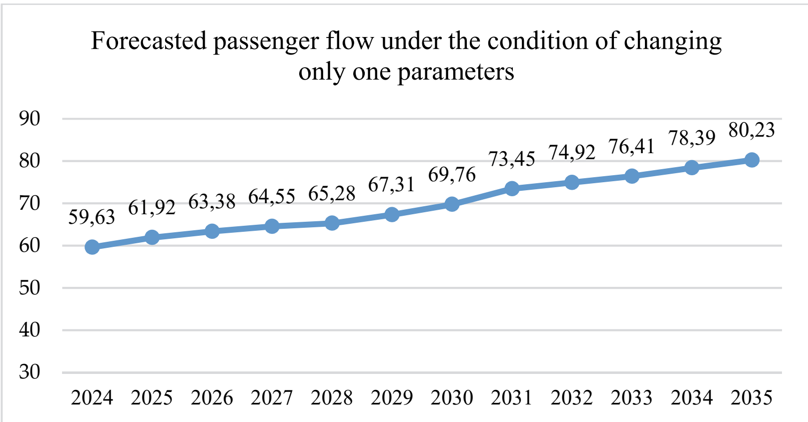

Figure 8 Forecasted passenger flow under the condition of changing only one parameter

Through the figure, it can be found that under the condition that the economic population growth trend remains unchanged, only the decrease of the additional investment growth ratio of the dedicated train will lead to a slower growth rate of passenger flow, and with the good development of economic and demographic conditions, the passenger flow of the dedicated train can still continue to grow. Similarly, in the low-speed development model, different parameters are adjusted. It is assumed that the population growth rate has a negative growth of 0.05%. At the same time, the operation department of the dedicated train reduces the operation chart, and the additional investment growth ratio of the dedicated train is adjusted from 3% to –0.5%, and the income investment ratio is adjusted from 4.7% to 2%. The adjusted passenger flow forecast results are shown in Fig. 9.

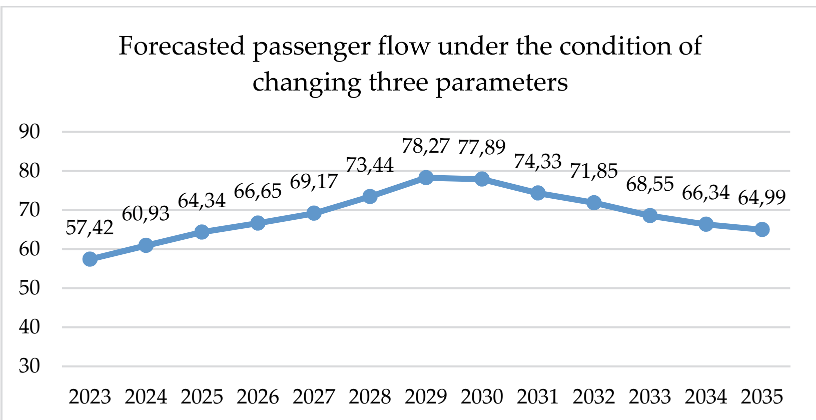

Figure 9 Forecasted passenger flow under the condition of changing three parameters

Tourist-dedicated train operation project is a dynamic development process, in which the impact of economic and population development on the environment is directly reflected in the level of passenger flow changes. It can be seen from Fig. 9 that it still maintained a slow growth from 2024 to 2029. This is because although the parameters have declined year by year, they have not completely returned to zero. In 2030, the passenger flow began to stop growing and declined year by year. The reason is that the impact of economic growth and negative population base growth has been strengthened, and the reduction in investment in special trains has led to the inability to improve service levels. Specifically, the increase or decrease of passenger flow is affected by the cause and effect of various factors in the system. Whether tourists choose to travel on the tourist-dedicated train is closely related to the investment of the tourist-dedicated train. These inputs include the upgrading and transformation of the equipment implementation in the system flow diagram, as well as the change of service level. The quality of tourist travel has a significant dependence on the service level, and the decrease of this dependence is also an important reason for the decrease of passenger flow.

6 CONCLUSION

Passenger flow forecasting is very important for the planning, design and market and operation of tourist-dedicated train projects, and it is a pre-step that cannot be ignored in the process of project operation.The tourist-dedicated train passenger flow is composed of three ways: trend, induced and transferred passenger flow. The causes of the three passenger flow modes are both relatively independent and related. This paper analyzes the causal relationship between population, economy, tourist-dedicated train facilities level, policy and competition, manpower and supply level and other factors related to train travel demand and the influence of each index, and constructs a forecasting model, and verifies the applicability of the SD model to the demand forecast of the tourist-dedicated train through different scale examples. The historical data verification shows that the model method has lower error than the three classical forecasting methods. In a large-scale example, by setting different development situation parameters, the forecast data of tourism passenger flow under three different economic population development trends are obtained. The research results show that it is very meaningful to carry out passenger flow forecasting for tourist-dedicated trains in the development and operation of tourist-dedicated trains. The passenger flow forecasting of tourist-dedicated trains by system dynamics method is feasible and effective. The introduction of this method provides a new research idea for solving this problem and similar problems.

Acknowledgements

The authors would like to thank for the "Double-First Class" Major Research Programs, Educational Department of Gansu Province (No. GSSYLXM-04).

7 REFERENCE

[1] Tsai, T. H., Lee, C. K., & Wei, C. H. (2009). Neural Network Based Temporal Feature Models for Short-Term Railway Passenger Demand Forecasting. *Expert Systems with Applications, 36*(2), 3728-3736. https://doi.org/10.1016/j.eswa.2008.02.071

[2] Wei, Y. & Chen, M. C. (2012). Forecasting the Short-Term Metro Passenger Flow with Empirical Mode Decomposition and Neural Networks. *Transportation Research Part C: Emerging Technologies*, *21*(1), 148-162. https://doi.org/10.1016/j.trc.2011.06.009

[3] Wang, Y., Zheng, D., & Luo, S. M., Zhan, D. M., & Peng, N. (2013). The research of railway passenger flow forecasting model based on BP neural network. *Advanced Materials Research*, *605, 2366-2369.* https://doi.org/10.4028/www.scientific.net/AMR.605-607.2366

[4] Jiang, X., Zhang, L., & Chen, X. (2014). Short-Term Forecasting of High-Speed Rail Demand: a Hybrid Approach Combining Ensemble Empirical Mode Decomposition and Gray Support Vector Machine with Real-World Applications in China. *Transportation Research Part C: Emerging Technologies, 44*, 110-127. https://doi.org/10.1016/j.trc.2014.03.016

[5] Jiao, P., Li, R., & Sun, T., Hou, Z., & Ibrahim, A. (2016). Three revised Kalman filtering models for short-term rail transit passenger flow forecasting. *Mathematical Problems in Engineering*, *795*, 1-10. https://doi.org/10.1155/2016/9717582

[6] Yin, Y. & Shang, P. (2016). Forecasting traffic time series with multivariate predicting method. *Applied Mathematics and Computation, 291*, 266-278. https://doi.org/10.1016/j.amc.2016.07.017

[7] Kon, S. C. & Turner, L. W. (2005). Neural network forecasting of tourism demand. *Tourism Economics, 11*(3), 301-328. https://doi.org/10.5367/000000005774353006

[8] Chen, M. S., Ying, L. C., & Pan M. (2010). Forecasting tourist arrivals by using the adaptive network-based fuzzy inference system. *Expert Systems with Applications, 37*, 1185-1191. https://doi.org/10.1016/j.eswa.2009.06.032

[9] Cho, V. (2003). A comparison of three different approaches to tourist arrival forecasting. *Tourism Management, 24*(3), 323-330. https://doi.org/10.1080/10941661003630001

[10] Sun, X., Sun, W., & Wang, J., Zhang, Y., & Gao, Y. (2016). Using a Grey-Markov model optimized by Cuckoo search algorithm to forecast the annual foreign tourist arrivals to China. *Tourism Management, 52*, 369-379. https://doi.org/10.1016/j.tourman.2015.07.005

[11] Yao, Y., Cao, Y., & Ding, X., Zhai, J., Liu, J., Luo, Y., Ma, S., & Zou, K. (2018) A paired neural network model for tourist arrival forecasting. *Expert Systems with Applications, 114*(30), 588-614. https://doi.org/10.1016/j.eswa.2018.08.025

[12] Zhong, Y., Jia, X., & Qian, Y. (2023). System dynamics. *Science press*.

[13] Wang, Q. (2009). System dynamics. *Science press*.

[14] Li, J., Luo, Y., & Wei, S. (2022). Long-term electricity consumption forecasting method based on system dynamics under the carbon-neutral target. *Energy, 244*, 122572. https://doi.org/10.1016/j.energy.2021.122572

[15] Tascón, D. C. & Olariaga, O. D. (2021). Air traffic forecast and its impact on runway capacity. A System Dynamics approach. *Journal of Air Transport Management*, 101946. https://doi.org/10.1016/j.jairtraman.2020.101946

[16] Suryani, E., Chou, S., & Chen, C. (2010). Air passenger demand forecasting and passenger terminal capacity expansion: A system dynamics framework. *Expert Systems with Applications, 37*(15), 2324-2339.

https://doi.org/10.1016/j.eswa.2009.07.041
[17] Feng, F. & Lan, D. (2012). Prediction of Railway Cargo Carrying Capacity in China Based on System Dynamics. *Procedia Engineering, 29*, 597-602. https://doi.org/10.1016/j.proeng.2012.01.010
[18] Mou, Z., Li, K., & Chen, Y., et al. (2021). Ridership forecast of high-speed railway based on the system dynamics. *Science Technology and Engineering, 21*(1), 387-394.
[19] Yang, Y., Yin, Y. X., & Wang, Y. P., Meng, R., & Yuan, Z. et al. (2023). Modeling of Freeway Real-Time Traffic Crash Risk Based on Dynamic Traffic Flow Considering Temporal Effect Difference. *Journal of Transportation Engineering Part A Systems, 14*9, 04023063. https://doi.org/10.1061/JTEPBS.TEENG-7717
[20] Zeng, C., Ma, C., & Wang, K., & Cui, Z. (2022). Parking Occupancy Prediction Method Based on Multi Factors and Stacked GRU-LSTM. *IEEE Access, 10*, 47361-47370. https://doi.org/10.1109/ACCESS.2022.3171330
[21] Yang, Y., Tian, N., & Wang, Y., Z., & Yuan, Y. (2022). A Parallel FP-Growth Mining Algorithm with Load Balancing Constraints for Traffic Crash Data. *International Journal of Computers Communications & Control, 17*(4), 4806. https://doi.org/10.15837/ijccc.2022.4.4806
[22] Zeng, C., Ma, C., & Wang, K., & Cui, Z. (2022) Predicting vacant parking space availability: A DWT-Bi-LSTM model. *Physica A: Statistical Mechanics and its Applications, 599*, 127498. https://doi.org/10.1016/j.physa.2022.127498
[23] Yang, Y., Yang, B., & Yuan, Z., Meng, R., & Wang, Y. (2023) Modeling and Comparing Two Modes of Sharing Parking Spots at Residential Area: Real-time and Fixed-time Allocation. *IET Intelligent Transport Systems*. https://doi.org/10.1049/itr2.12343
[24] Ma, C., Wang, C., & Xu, X. (2021). A Multi-Objective Robust Optimization Model for Customized Bus Routes. *IEEE Transactions on Intelligent Transportation Systems, 22*, 2359-2370. https://doi.org/10.1109/TITS.2020.3012144
[25] Ma, C., Dai, G., & Zhou, J. (2022). Short-Term Traffic Flow Prediction for Urban Road Sections Based on Time Series Analysis and LSTM_BILSTM Method. *IEEE Transactions on Intelligent Transportation Systems, 23*, 5615-5624. https://doi.org/10.1109/TITS.2021.3055258
[26] Liu, S. (2017). Grey system theory and application. *Science press*, 92-116.
[27] Liu, S., Jian, L., & Mi, C. (2017). Management Forecasts and Methods. *Science press*, 62-90.

Contact information:

Yuanding CUI
(Corresponding author)
School of Traffic and Transportation,
Lanzhou Jiaotong University
E-mail: 0118001@stu.lzjtu.edu.cn

Yinzhen LI
School of Traffic and Transportation,
Lanzhou Jiaotong University
E-mail: 1242025005@qq.com

Changxi MA
School of Traffic and Transportation,
Lanzhou Jiaotong University
E-mail: machangxi@mail.lzjtu.cn