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Forecast and Analysis of Road Transportation Energy Demand under the Background of System Dynamics

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Abstract. By analyzing the relationship between urban road transportation energy demand and economy and passenger transportation, the dynamic model of road transportation energy demand system in Beijing is built, and the road transportation statistics are applied to the system anyway. The results show that the system can overcome the shortcomings of road transportation forecasting, and verify the feasibility of the system. It has decision-making reality and predictability for the analysis of road transportation energy demand.

1. Introduction

In the process of modern social development, energy has become an indispensable asset. It involves not only the people's livelihood, but also national security, which is the support of the national economy. As the industry with the highest energy demand per unit of output value, the transportation industry's rapid increase in energy consumption not only brings long-term and serious threats to China's energy security, but also pollutes the environment due to higher emissions. Due to its flexibility and universality, road transport is closely related to people's lives and closely linked to national energy. This paper conducts energy demand forecasting and scenario simulation for Beijing road transport system, and provides theoretical basis for energy saving and emission reduction and development of green transportation in Beijing [1-2]. The paper first determines the causal relationship between road transport and social economy, population, passenger transport, freight turnover and energy demand in Beining City, and establishes a causal relationship map. Based on this, the road transport energy demand in Beijing is constructed. The system dynamics model, and the application of this model for road transport energy demand forecasting and related scenario simulation, and finally, the analysis of Beijing energy conservation and emission reduction, the development of green transportation related recommendations.

2. Road transportation energy demand calculation

According to the General Principles of Comprehensive Energy Consumption, GBT2589-2008 and related literature, the calculation formula of energy demand is as follows:

$$E=\sum\left(e_i \times p_i\right) \tag{1}$$

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E: comprehensive energy consumption; e_i : physical quantity of the *i-th* energy consumed in production and service activities; p_i: conversion factor of the *i-th* energy, converted according to the equivalent value of energy or the value of energy. The road transportation energy demand expression is as follows [3].

$$e=\sum\left(N_i \times G_i \times M_i\right) \tag{2}$$

E: Total fuel consumption of vehicles in road transportation; N_i: Vehicle ownership; G_i: Average fuel consumption per 100 kilometers of vehicle type; M_i : Average annual mileage of vehicle type *i*, the following expression is obtained.

$$e=\sum\left(V_i \times R_i\right) \tag{3}$$

E: Road transportation energy demand; V_i: turnover of various types of transportation modes in road transportation; R_i: unit turnover energy consumption of each type of operation mode.

The energy calorific value is converted into a standard coal conversion coefficient, and the average calorific value and the converted standard coal coefficient are calculated as follows.

$$\overline{e}=\sum\left(e \times n\right) \div \sum N \tag{4}$$

$\overline{e}$: Average calorific value (kcal/kg); e: measured energy low calorific value (kcal/kg); n: quantity of energy (t); N: quantity of energy (t).

3. Structure and characteristics of urban road transport system

The urban road transportation system is a part of the social economic system. A distinctive feature of the social economic system is the complexity of the system structure. This complexity is not only reflected in the structure of the system elements themselves, but also in the connections between the various system elements. Therefore, the study of urban road transport cannot be limited to urban transport itself, and it is necessary to conduct comprehensive and comprehensive research on government agencies, transportation departments, and users from the social economic system [4].

As an important part of the socio-economic system, the road cargo transportation system does not exist independently and is subject to various external factors. The ultimate goal of road cargo transportation is to meet the needs of production and life. Industrial and agricultural production, people's consumption levels, population size and layout will determine their supply and demand; road transport industry structure, economic layout, freight rate, social resources and environmental protection policies will affect their investment direction, investment scale, transportation resources Configuration; an obvious feature of modern logistics is informational and networking, so the level of technology is an important prerequisite for its transformation into modern logistics.

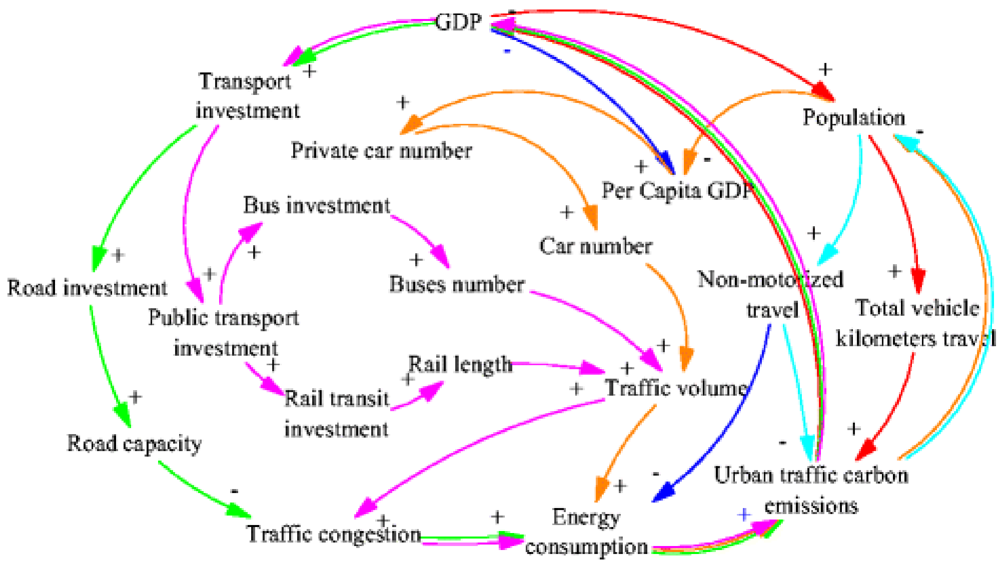

Fig. 1 Causal relationship of road transport energy demand in Beijing

4. Road transport energy demand system dynamics model construction

Combined with the analysis of system causality, the Venism software is used to construct the SD (system dynamics) flow diagram, as shown in Figure 2.

4.1. Passenger demand model

Passenger transportation demand comes from the needs of social and economic activities, and is affected by many factors such as population size, economic development level, consumption level of residents, seasonal fluctuations and the development of tourism. The system dynamics model equation is as follows.

$$
\begin{aligned}
&{}_{L}KYXQL_{K} = KYXQL_{J} + DT * KYXZR_{JK} \\
&{}_{R}KYXZR_{KL} = EKYZA * GDP_{K} + ETRKA_{K} * ERJCA_{K} * RKZZC \\
&{}_{A}ERJCA_{K} = GDP_{K} * EKYSA
\end{aligned} \tag{5}
$$

Where: L represents the state equation; R represents the rate equation; A represents the auxiliary equation; K, J, JK, and KL are time subscripts, indicating the current time, the previous time, the previous time period, and the current time period; For the simulation time interval (step size), this article takes 1 year. EKYZA represents customer influence parameters, KYXQL represents passenger demand, KYXZR represents customer demand growth rate, ETRKA represents population, RKZZC represents population growth rate, ERJCA represents per capita number of rides, EKYSA reaches standard impact ride, and EPYJT stands for average transport distance [5].

4.2. Freight Demand Model

The demand for freight increases with the development of the economy, and the increase in demand for freight drives economic growth.

$$
\begin{aligned}
&{}_{L}HYXQL_{K} = HYXQL_{J} + DT * HYQZR_{JK} \\
&{}_{R}HYQZR_{KL} = HYXST * GNYZZA_{K} + THPZT * DSCZZA_{K} \\
&{}_{A}GNYZZA_{K} = GYCZA_{K} + NYCZA_{K}
\end{aligned} \tag{6}
$$

THPZT represents the influence parameters of the squad expansion, DSCZZA represents the total output value of the tertiary industry, HYXQL represents the freight demand, HYQZR represents the growth rate of freight demand, GNYCGA represents the total output value of the first and second industries, GYCZA represents the total output value of the secondary industry, and NYCZA represents the total output of the primary industry. Production value, HYXST represents the freight demand growth multiplier.

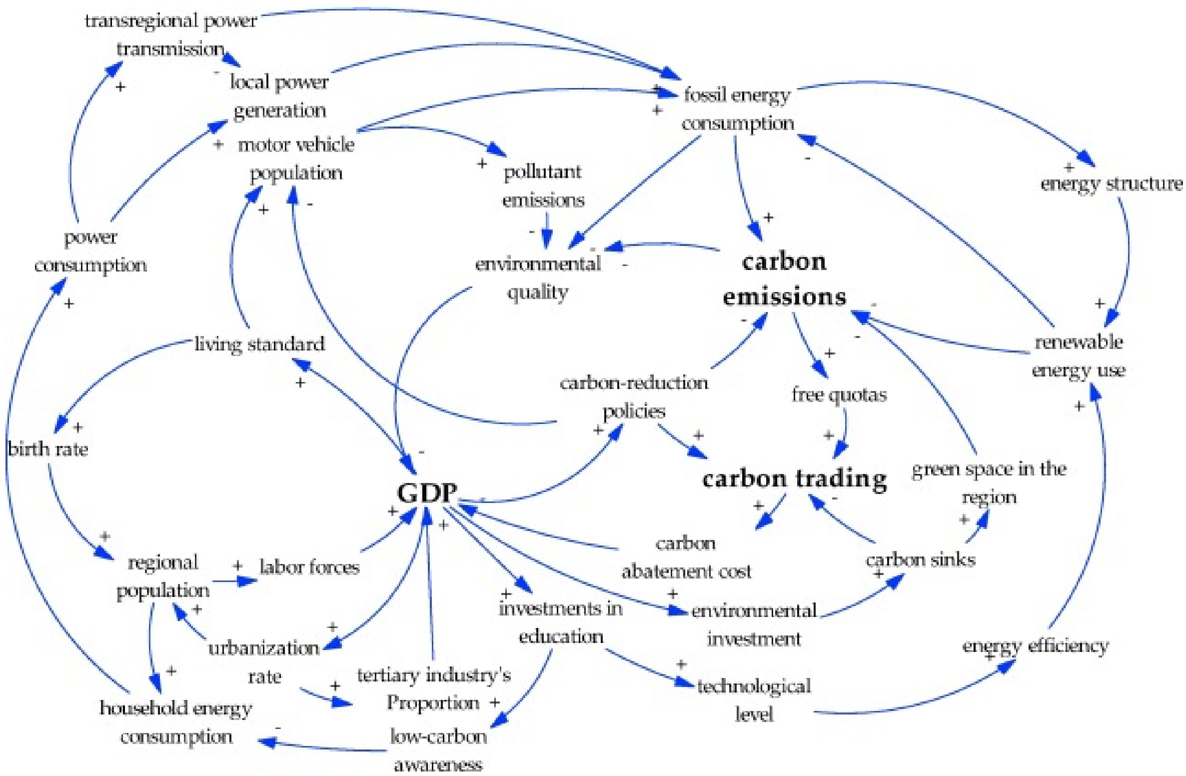

Fig. 2 SD model of road transport energy demand

4.3. Passenger Supply Model

The supply of highway passenger transportation is mainly affected by the state input, passenger transportation revenue, and passenger traffic volume. The dynamic equation is as follows.

$$
\begin{aligned}
&_L KCZSL_K = KCZSL_J + \left(DT * KCZZR_{JK} - KCBFR_{JK} \right) \\
&_R KCBFR_{KL} = KCBFC * KCZSL_K \\
&_R KCZZR_{KL} = KCZZT * GDPL_K + KCZZC * KSYYXA_K \\
&_A KSYYXA_K = SMOOTH\left(KYSYA_K , PHSJC \right) \\
&_A KYSYA_K = KSYCST * KYCGA_K
\end{aligned} \tag{7}
$$

GDP represents GDP, KCZZT represents the country's passenger car control parameters, KCBFC represents passenger car scrap parameters, KCZZR represents bus growth rate, KCZSL represents passenger car total, KCBFR represents passenger car scrap rate, KCZZC bus revenue impact adoption number, KSYYXA represents passenger car revenue impact Smoothing function, KYSYA represents passenger revenue, KYCGA represents passenger traffic, KSYCST reaches passenger revenue parameters.

4.4. Freight Supply Model

The supply of road freight is mainly affected by national input, freight self-revenue, and completed freight volume. The dynamic equation is as follows.

$$\begin{aligned}
&{}_L\,HCZSL_K = HCZSL_J + DT * \left(HCZZR_{JK} \text{-} HCBFR_{JK}\right) \\
&{}_R\,HCBFR_{KL} = HCBFC * HCZSL_K \\
&{}_R\,HCZZR_{KL} = HCZZT * GDPL_K + HCZZC * HSYYXA_K \\
&{}_A\,HSYYXA_K = SMOOTH\left(HYSYA_K, PHSJC\right) \\
&{}_A\,HYSYA_K = HSYCST * HYCGA_K
\end{aligned} \tag{8}$$

HCZZT stands for national control parameters for trucks, HCBFC stands for truck scrap parameters, HCZZR stands for truck growth rate, HCZSL stands for trucks, HCBFR stands for truck scrap rate, HCZZC stands for truck revenue impact parameters, HSYYXA stands for freight yield parameter smoothing function, and HYSYA stands for freight income [6], OHSJC stands for smoothing time, HYCGH stands for total freight, and HSYCST stands for freight income parameter.

5. Forecasting and scenario simulation

5.1. Passenger and freight turnover forecast

Use the model to predict the passenger and cargo turnover during the 13th Five-Year Plan period, as shown in the table below.

Tab.1 Passenger and freight turnover forecast results

time	Passenger turnover / 100 million kilometers	Freight turnover / 100 million tons
2018	1126.81	12,494.70
2019	1195.26	12,709.66
2020	1263.57	13030.59
2021	1321.42	13329.46
2022	1384.29	13500.75
Average annual growth rate /%	4.2	2.38

5.2. Energy demand and carbon dioxide emissions forecast

The author predicts the demand for road passenger and freight energy and total carbon dioxide emissions during the 13th Five-Year Plan period. The results are shown in Figure 3.

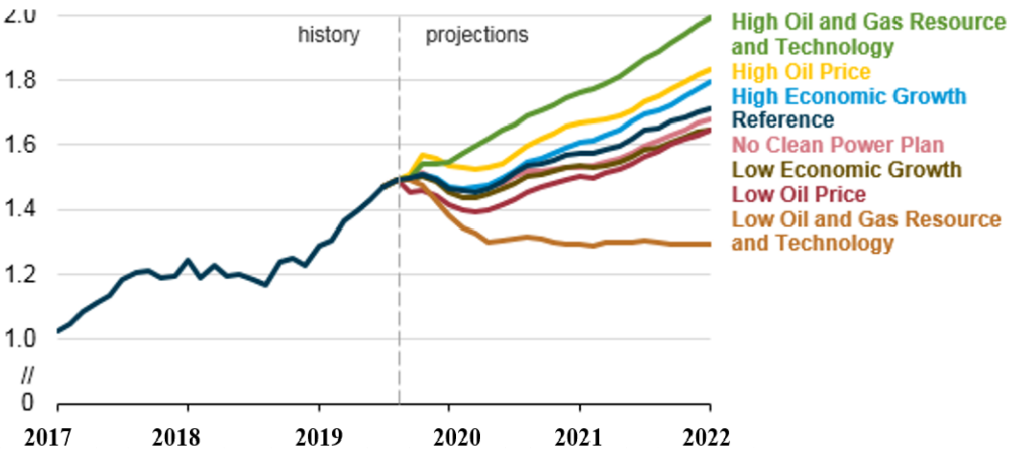

Fig. 3 Energy demand and carbon dioxide emissions forecast results

The demand for road transport energy in Beijing has increased year by year, and the carbon dioxide emissions have also increased year by year, and the overall growth trend has slowly increased to a rapid increase to a faster increase.

5.3. Parameter verification of the model

In the construction process of this model, the meaning of the parameters and the range of values of the parameter values are tested at the same time. After the model design is completed, the parameter sensitivity test is performed. Since the model contains a large number of parameters, when performing the sensitivity analysis, the key parameters in some models are generally selected, instead of analyzing all the parameters. In the urban road transport SD model, sensitivity analysis was carried out on investment policy parameters and various vehicle transportation demand parameters.

5.4. Validity test of the model

The validity test of the model actually evaluates the moderation of the model structure by analyzing the behavior generated by the structure. In this model, the validity of the main variables is tested. By comparing the difference between the system variable simulation and the historical data to judge the validity of the model, the error between the simulated value and the actual value of the running result of the model is relatively small, and it can be considered that the model has passed the validity test.

6. Conclusion

In this study, the system dynamics method is applied to the qualitative analysis of various influencing factors and intrinsic relationship of road freight transportation system, and the system dynamics model is established to carry out dynamic prediction and quantitative analysis of road freight transportation system. After the road to Jilin Province the simulation analysis of the cargo transportation system verified the practicability and effectiveness of the model. Due to the tremendous changes in society, the adjustment of the structure of the road transport industry and the adjustment of the economic layout, many complicated factors such as economy, science and technology, policy, social resources and environmental protection play an important role in the development of road freight transport. Therefore, in road transport in the macro analysis and strategic planning of the system, using the system dynamics method to comprehensively consider these influencing factors, it can provide decision support and applicable predictive analysis methods for the road transport management department.

References

[1] Li Zhipeng. Urban Transportation Energy Consumption and Carbon Emission Prediction Based

on System Dynamics.Vol.3 (2012) No.34, p. 137-139.
[2] He Nan.System Dynamics Prediction and Analysis of Urban Passenger Transport Demand.Journal of Wuhan University of Technology (Transportation Science & Engineering), Vol.4 (2017) No.41, p.33-36.
[3] Zhang Jing. Quantitative study on traffic volume risk of PPP highway project based on system dynamics.Vol.1 (2017) No.15, p.15-19.
[4] Cao Dongping.Study on Simulation and Prediction of Ecotourism Environment Carrying Capacity Based on System Dynamics.Vol.5 (2017) No.25, p.25-30.
[5] Xu Changxin,Yan Yixin,Zhang Ping.Port throughput prediction model based on system dynamics.Water Transport Engineering,Vol.5 (2006) No.21, p.26-28.
[6] CHEN Yaqing,HAN Yunxiang.A Prediction Model of Passenger Traffic Volume in Aviation System Based on System Dynamics.Traffic information and security,Vol.5 (2009) No.27, p.146-148.