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RESEARCH PAPER

Energy Consumption Driving Factors and Measuring Models of Regional Integrated Transport System

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Abstract: To identify the energy consumption driving factors and measure their corresponding contributions in energy consumption, the paper classifies the factors into scale effect, structure effect and technique effect according the driving mechanism. It then analyzes the correlations between these factors by ASIF data structural principles and the time series regression. The contributions of these factors are measured via the expanded LMDI decomposition model based on the LMDI method. The result indicate that: (1) the impacts from scale effect and technique effect are weakening, while that from structure effect is increasing; (2) the transport supply structure needs to be further optimized, and there exists plenty of space for reducing the impact on energy consumption; (3) the energy efficiency has increased a lot in recent years, but its contribution to energy consumption is shrinking. Improving the transport intensity exerts significant effect on saving energy. The reliability of the models and its conclusions is proved by empirical studies, which provides scientific supports for the policy making of regional low-carbon integrated transport.

Key Words: integrated transportation; regional transportation; energy consumption; driving factors; measuring models

1 Introduction

Seeking the energy consumption driving mechanism of regional comprehensive transportation and measuring its affecting factors in a scientific manner are the most fundamental theoretical foundations to establish the low-carbon transportation energy consumption control policy. There is a multitude of related research achievements conducted in this manner. Among these achievements, one is to analyze the energy consumption affecting factors of regional transportation from macro perspective, and put forward the development model of low-carbon transportation. Zheng *et al*.[1] provided the development framework of large city low-carbon passenger transportation systems which were supported with the "strategic level", "tactic level" and "operation management level". Lai and Ren[2] proposed the development model with the interaction among three differing groups including, "government, transportation enterprise, and public". The other is to decompose the energy consumption affecting factors of regional transportation by measuring the contribution of each factor and determine an energy consumption control strategy. Zhang *et al*.[3] has developed the kinetic model of urban low-carbon transportation systems, and determined that the increase of vehicle population and city population is an important driving factor. Ferdinand *et al*.[4] decomposed the energy consumption and carbon emission factors of the USA in 1990 to 2004 with the LMDI method. Sorrell *et al*.[5,6] have respectively decomposed the energy consumption and carbon emission factors of UK and Lithuania. Zheng *et al*.[7] studied the large city passenger transportation energy demand variation factors with the Lasperyres decomposition method. Zhou *et al*.[8] analyzed the coordination relation between energy consumption in the development of comprehensive transportation. Xu and Tang[9] predicted the transportation energy consumption in Guangdong Province with the Microsoft time series method. Li *et al*.[10] investigated the dynamic relationship between energy efficiency and economic growth in the transportation industry. Lastly, Zheng and Zhang[11] evaluated the energy consumption affecting factors of China's regional transportation from four aspects, i.e., natural geographical environment, transportation structure, economic development level and traffic network density. In summary, there are many analysis on qualitative factors and experience references

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among current researches and more specifically on urban transportation. Numerous documents are based on quantitative decomposition of energy consumption affecting factors. Most documents do not provide the systematic analysis of transportation energy consumption driving mechanisms and the determination of energy consumption driving factors. The end result is the difficulty to explain the scientific aspect of energy consumption driving factors. As an outcome, this paper begins with the inherent driving mechanism, and then identifies the energy consumption driving factors of regional comprehensive transportation system. Lastly, it generates a model that measures every factor's contribution, and provides the methodological base for formulating regional transportation energy consumption control policy.

2 Identification of energy consumption driving factors

The energy consumption of regional comprehensive transportation system is convoluted. By occurrence sources, it can be divided into four sections including energy consumption of highway transportation, railway transportation, civil aviation transportation and waterway transportation. The energy consumption intensity and total energy consumption of each transportation mode varies largely, and the energy consumption of comprehensive transportation systems in different transportation structure conditions is not always the same. Therefore, the identification of the energy consumption driving factors of regional comprehensive transportation system should consider not only the individual factors of every transportation mode, but also the overall structural factors of the comprehensive transportation system.

There are many factors affecting the energy consumption of comprehensive transportation systems. Logically, some factors include economic development level, population scale, transportation scale, transportation intensity, transportation structure and energy efficiency. Whether positive or negative, each factor has a different impact on the system energy consumption. Thus, scientific identification is required to distinguish which factors are the key factors and main control points for system energy consumption.

According to the ASIF (activity, structure, intensity and fuel) data structural principles in the IAEA/MAED model and in consideration of data availability, this paper selects five indices; regional per capita GDP, regional population, transportation turnover for unit GDP, proportion of the turnover of every transportation mode to total turnover and energy consumption for unit turnover. These five are chosen as initial variables of the energy consumption affecting factors of regional comprehensive transportation systems. Then, a correlation analysis to determine the relevance between each is conducted. The key variables of the energy consumption affecting factors of regional comprehensive transportation systems are then fixed using the correlation analysis and time series regression methods.

The relations among the energy consumption affecting factors are shown in Fig. 1.

Wherein, per capita GDP is used to indicate economic development level and represented with "L"; population quantity is used to indicate population scale and represented with "P"; transportation turnover for unit GDP is used to indicate transportation intensity and represented with "K"; proportion of the turnover of every transportation mode to total turnover is used to indicate transportation structure and represented with "S"; energy consumption for unit turnover is used to indicate energy efficiency and represented with "G"; then, the following formulas are obtained:

$$L=GDP/P,\ K=Q/GDP,\ S_i=Q_i/Q,\ G_i=E_i/Q_i$$

where i is the different transportation modes, E is energy consumption, Q is transportation turnover and P is regional population.

3 Model to measure contribution of driving factors

Generally, there exist two major methods for the measurement of the energy consumption affecting factors' contribution to regional comprehensive transportation. One begins from top to bottom and the other is from bottom to top. The factor decomposition method, the index decomposition method, the scenario analysis method and the regression analysis method are among the most popular methods. Wherein, Ang[12] has brought forward the LMDI decomposition method, which belongs to the method from bottom to top. This method works effectively on a theory basis, adaptability, operability and result presentation. It also provides measurement result without residual, convenient application and specific result expression, and thus has been recognized as a flawless decomposition method. No additional details are described for this method; the focus is on creating the model to measure the energy consumption affecting factors' contribution using this method.

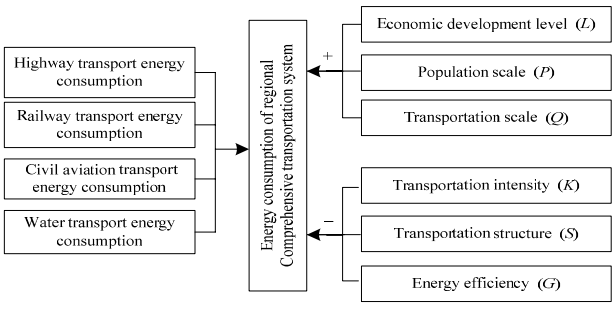

Fig. 1 Relation diagram of systemic energy consumption affecting factors