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Estimation and Convergence Analysis of Traffic Structure Efficiency Based on an Undesirable Epsilon-Based Measure Model

Xudong Cao, School of Automotive and Transportation Engineering, Hefei University of Technology, China

Chenchen Chen, College of Civil Engineering, Anhui Jianzhu University, China

Lejia Zhang, Guilin University of Electronic Technology, China

Li Pan, UCSI University, Malaysia*

ABSTRACT

To improve transportation efficiency, this paper analyzes the factors of transportation structure from the two levels of transportation—input and system output. An epsilon-based measure model of non-expected output is introduced, and the environmental benefits of transportation are considered. This model is used to analyze the regional transportation efficiency of 30 provinces and cities in China. Tobit regression and geographically weighted regression are applied to analyze the causes and spatial variation of differences in the efficiency of the transportation structure, and corresponding structural adjustment strategies are proposed. The results show that the regression coefficients of the share of secondary industry output in GDP, population density, and social fixed asset investment exert the most significant effects on transportation structure efficiency. The spatial distribution of sub-variable coefficients shows that spatial heterogeneity exists in the degree of influence of various socio-economic factors on the transportation structure efficiency in different regions.

KEYWORDS

Epsilon-Based Measure, Environmental Benefit, Geographic Weighted Regression, Tobit Regression, Traffic Structure Efficiency

INTRODUCTION

The construction and continuous development of the transportation industry greatly promotes the interconnection of regional industries, resources, and people and also enables sustainable economic growth (Prus & Sikora, 2021; Tian et al., 2020). According to the statistical bulletin on the development of the transportation industry published in 2022 by the Ministry of Transport of China, at the end of 2021, China invested 3,622 billion yuan annually into transportation fixed assets, which signifies an increase of 4.1% over the previous year (Ministry of Transport of the People's Republic of China, 2022). The railroad mileage has a length of 150,000 km, of which 40,000 km is suitable for high-speed rail. The national railroad network density is 156.7 km per 10,000 km,[2] and the total road mileage is

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5,280,700 km, with a road density of 55.01 km per 100 km.[2] The total road mileage is 5,280,700 km, with a road density of 55.01 km per 100 km,[2] of which the highway mileage is 169,100 km, accounting for 3.2%. The inland waterways have a navigable mileage of 127,600 km and 20,867 berths for port production. Regarding transportation services, the annual operating passenger volume reached 8.303 billion people, which reflects a 14.1% decrease compared with the previous year. Passenger turnover is 1,975,815 million person-km, reflecting an increase of 2.6%. Operating freight volume is 52.160 billion tons, reflecting an increase of 12.3%, and completed cargo turnover is 21.8 trillion-ton km, reflecting an increase of 10.9%.

However, as a pillar industry for social and economic development, the transportation industry is characterized by concentrated investment, intensive energy consumption, and large pollution emissions. In 2020, the total energy consumption of China's transportation industry was about 413 million tons of standard coal, accounting for 8.29% of China's total energy consumption (Ministry of Transport of the People's Republic of China, 2022). In response to the surge of motor vehicle ownership, the total pollutant emissions from motor vehicles have also increased year by year. According to data released by the Chinese Ministry of Ecology and Environment, the total emission of four key pollutants from motor vehicles nationwide in 2020 was 15.930 million tons. Among them, carbon monoxide (CO), hydrocarbons (HC), nitrogen oxides (NOx), and particulate matter (PM) emissions were 7.697 million tons, 1.902 million tons, 6.263 million tons, and 68,000 tons, respectively. Automobiles are the main contributor to total pollutant emissions, and their CO, HC, NOx, and PM emissions exceed 90% of the total motor vehicle emissions. The above data indicate that with increasing investment in the transportation industry and the continuous improvement of the transportation infrastructure, the demand for inter-regional passenger and cargo transportation is also increasing. At the same time, the scale of development of various modes of transportation and the amount of transportation undertaken vary greatly. The potentially resulting imbalances of the transportation structure will not only lead to an unreasonable distribution of social and economic resources, but also cause severe environmental pollution (Du et al., 2022; Li et al., 2021; Qiang et al., 2018). Therefore, in today's important period of transportation restructuring, measuring the efficiency of the transportation structure, continuously optimizing the transportation system, and realizing green, circular, and efficient transportation development have become key issues.

The transportation structure is a pattern of goods and people flow that formed under the specific conditions of spatial layout, population density, economic development, and social and natural environments. The transportation structure reflects the division of labor, organic combination, connectivity, and reasonable layout of the transportation complex. This complex is composed of various modes of transportation in the scope of socialized transportation and a unified transportation process according to technical and economic characteristics (Wei et al., 2021; Gao & Wang, 2021). As a result, the transportation structure can visually reflect the regional transportation strategy (Verma et al., 2021). To measure the rationality of the transportation structure system and the efficiency of coordination and cooperation between transportation modes, many scholars have studied the efficiency of the transportation structure from different perspectives (Lin & Wang, 2022; Zhai et al., 2019; Zeng & Wei, 2021; Kotikov & Kravchenko, 2020). Ganin et al. (2017) defined transportation system efficiency as the average annual delay time car commuters experience during peak hours. They developed and calibrated a model that uses link loads to evaluate traffic delays. Barnum et al. (2011) studied various technical efficiencies and resource allocation efficiencies between different transportation modes from a resource allocation perspective to assess the overall efficiency of urban public transportation. Guo et al. (2018) studied the passenger capacity that can be achieved by public transportation using the inputs of station density, station design, and years of operation to assess the efficiency of transit-oriented development (see also Salman et al., 2022). Existing research and practical experience clearly show that the reasonable allocation of capital investment, the promotion of the division of labor, collaboration among various modes of transportation, and the improvement of the efficiency of the integrated transportation system are urgently needed. These actions can