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Research Article

Data Modeling of Impact of Green-Oriented Transportation Planning and Management Measures on the Economic Development of Small- and Medium-Sized Cities

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With the rapid growth of urbanization and motorization in China in recent years, the demand for transportation in people's work and daily lives has increased. In this context, a number of issues such as urban traffic congestion, energy consumption, and environmental pollution have become increasingly severe. As a result, the tremendous socioeconomic, resource, and environmental pressures have been placed on the development of urban transportation. Sustainable economic and social development requires green development as a precondition. The economical and efficient use of resources and the protection and improvement of the ecological environment are conducive to the formation of a new pattern of modernization for the harmonious development of man and nature. Transportation planning is an essential technical field for promoting the development of green and ecological cities, and it is one of the primary responsibilities of urban planning. The application of green ecological planning technology and the scientific and reasonable development of traffic planning and management measures can aid in reducing energy consumption and, thus, achieving the goal of environmental protection. In this field, green transportation is a mature green ecological planning technology. Green transportation development is not only a key solution to urban transportation problems, but also an essential means of achieving sustainable urban development, so it has become a hot topic in the field of transportation. As the ideal city of the postindustrial era, ecocity can serve as a model for the sustainable development of China's small and medium-sized cities. After all, industrial development is an unsustainable path, so human society must embrace green development. The core of green development lies in shifting from an exclusive reliance on industrialization to the urban transformation into an ecological civilization. Given the current contradictions between economic growth and resource and environmental degradation, promoting green and environmentally conscious transportation planning with resource conservation in mind is a crucial means of resolving these contradictions. Government incentives and restrictions are essential for the development of green transportation. Therefore, it is crucial to study the impact of environmentally conscious transportation planning and management measures on the economic growth of small and medium-sized cities. This will provide relevant departments and stakeholders with guidance and a reference for formulating policies that will contribute to the harmonious development of China's green transportation and economy.

1. Introduction

Transportation, as a vital lifeline for social development, is a crucial material production sector that ensures the smooth division of labor in the region and promotes national economic development [1]. To be specific, transportation can organically connect the production, distribution, exchange, and consumption of goods. Transportation plays a crucial role in promoting the rational flow of production factors, such as talents, [2] capital, information [3], and resources [4], and in fostering social and economic growth. Small cars have become more and more popular and have taken over as the general public's mode of transportation, particularly in the twenty-first century. However, from the perspective of

protecting the ecological environment, the transportation industry is destructive in terms of both energy consumption and environmental pollution [5]. As a result, as economic development accelerates urbanization and the urban population continues to grow, so does the demand for urban residents to travel. In this context, the increasing number of private cars has led to an increase in transportation energy consumption and greenhouse gas emissions, resulting in urban traffic congestion, air pollution, and urban heat island effect. Therefore, these phenomena pose a number of threats to sustainable urban development [6]. The transportation industry, as an important part of economic development, must take the initiative to assume the social responsibility of achieving a coordinated development between economic growth, environmental protection, and social harmony. Under this development concept, green transportation has emerged [7]. Therefore, green transportation has become a new driving force for economic development, in line with the current social trend.

In response to climate change, many countries around the world have begun to promote green and low-carbon transportation systems [8]. The goal of carbon neutrality also places significant demands on the sustainable development of the transportation sector [9]. As a result of rapid urbanization, China's motor vehicle ownership is increasing, and traffic congestion and air pollution are becoming increasingly prominent. In recent years, the average annual growth rate of carbon emissions in China's transportation sector is more than 5%, making it the fastest-growing sector in terms of greenhouse gas emissions, with total emissions accounting for about 15% of the country's total carbon emissions [10]. As a result, improving the transportation environment and developing green transportation are closely related to the goal of achieving carbon neutrality in China. In recent years, with the rapid development of China's economy and the acceleration of urbanization, the motorization of urban transportation has also expanded rapidly, and the number of urban motor vehicles has increased rapidly [11]. As shown in Figure 1, in 2013, there were only 32.56 million private cars in China, but this number reached 273.46 million in 2021 [12]. Therefore, private car ownership in China continues to grow, which indicates that more and more residents are inclined to use cars [13]. Nevertheless, this trend can not only cause negative impacts on the rapid development of public transportation, but also worsen the urban traffic structure [14]. The increase of urban motor vehicles has brought about a series of severe issues, such as traffic congestion, environmental pollution, accelerated energy consumption of resources, and noise disturbance, which seriously affect the process of sustainable urban development [15].

The rapid expansion of motor vehicles has brought tremendous pressure on urban traffic in China [16]. As a result, many small and medium-sized cities are experiencing serious problems such as traffic congestion. During the daily morning and evening rush hours, there are especially long queues of vehicles [17]. This significantly reduces the efficiency of urban roads and, as a result, increases the likelihood of traffic accidents, which negatively impacts the ability of urban residents to enjoy quality travel services [18]. To meet the growing demand for transportation, cities are expanding their transportation infrastructure. This process takes up nonrenewable resources such as land and construction materials, which is not conducive to sustainable transportation development [19, 20]. At the same time, motor vehicles consume a lot of fossil energy, which is also a major source of air pollution [21]. As a result of the unprecedented socioeconomic and environmental pressure on resources, the mode of urban transportation development now faces greater challenges [22]. The development of urban green transportation is not only an important solution to urban transportation problems, but also an inevitable choice for sustainable urban development and has evolved into a topic of national significance.

With the rapid advancement of economic development and urbanization, the urban traffic travel rate and travel distance increase, resulting in a conflict between economy and traffic demand and between traffic and environment. On the one hand, through systematic analysis of the mechanism of urban green transportation development, it is helpful to grasp the law of urban green transportation development [23]. This will aid in identifying the most influential factors and in proposing effective measures to promote the development of green transportation in cities. On the other hand, by establishing a set of applicable urban green transportation development evaluation index system and studying the level of urban green transportation development based on empirical data, we can quantitatively grasp the development trend of green transportation through evaluation [24]. Thus, the shortcomings and deficiencies can be identified, and relevant departments can be provided with reference bases for taking targeted measures. The evaluation scope of green transportation includes two aspects. The first one is to evaluate the development status of transportation in cities that have been engaged in green transportation construction for a long time [25]. According to the evaluation results, the development level can be determined and corresponding improvement measures and policies can be proposed. What is more, for cities that have only carried out transportation planning without green transportation construction or have been under construction for a short period of time, the planning options are evaluated. Then, according to the evaluation results, we can select and adjust the plan.

In addition, research on the relationship between transportation and economic development has been a topic of intense interest in a variety of disciplines, such as transportation economics, regional economics, and development economics. In the existing literature, most of the studies have been conducted on external urban public transportation such as railroads, roads, and terminals [26]. However, the role of urban public transportation, as the main internal public transportation task of cities, in the process of economic development has received scant attention, especially in terms of empirical analysis [27]. As a driving force of economic transformation and social progress, transportation should adapt to the shifting production, lifestyle, and travel consumption patterns of people. At the same time, giving priority to the development of urban

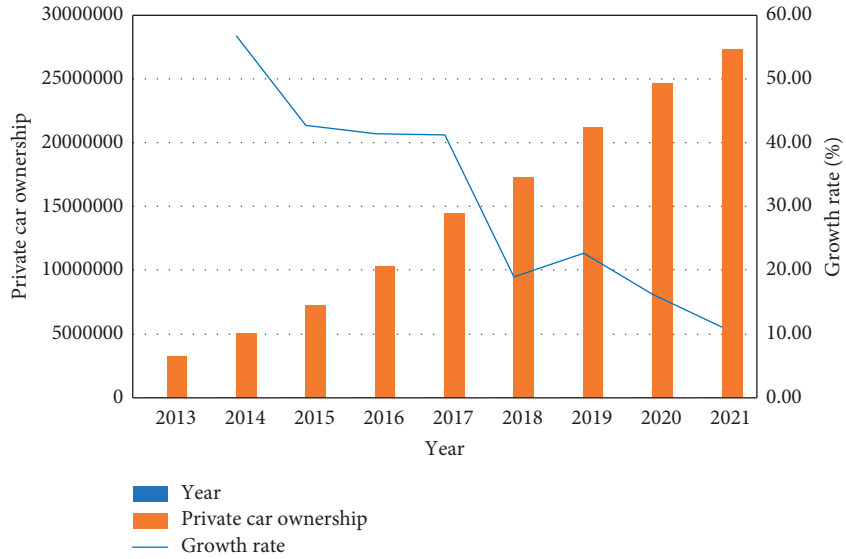

Figure 1: Private car ownership from 2013 to 2021 in China.

public transportation is the way to promote the thorough integration of transportation and economic and social development [28]. As a result, it is of great practical significance to conduct an empirical study on the impact of urban public transportation development on the green economy in conjunction with the current new economic development model of green economy [29].

Currently, major cities devote a significant amount of manpower and resources to the construction of fundamental transportation infrastructure. To be specific, the total area of urban roads and their network capacity are expanding, but the supply-and-demand disparity for roads remains severe [30]. As a result, many small and medium-sized cities in China are experiencing heavy traffic congestion, which drastically reduces the quality of the transportation system's service. In recent winters, major northern cities across the country have been plagued by haze, and air quality has significantly deteriorated everywhere. As a result, many cities have had to implement restrictions on construction site closures and car traffic [31]. However, most of these emergency measures are not effective at treating the symptoms. One of the major sources of urban pollution is traffic pollution. The rapidly increasing number of motor vehicles is exacerbating this situation and is becoming a major source of urban environmental pollution. The fast-paced socioeconomic development requires a green urban transportation system that is in harmony with it [32]. The root cause of urban environmental degradation is closely related to urban transportation planning.

Green transportation is a new type of urban transportation system proposed to improve urban transportation efficiency, promote social equity and stability, save construction and maintenance costs, reduce traffic congestion, and reduce environmental pollution. Due to the different levels of green transportation development in different cities and the uncoordinated development of green transportation subsystems, it is difficult to make the most effective use of green transportation system because of the poor connection between green transportation modes. Also, urban traffic problems have seriously restricted the healthy development of cities. Therefore, how to maintain rapid economic growth while considering ecological stability, to achieve sustainable urban development and sustainable use of transportation resources, is a problem that must be faced and solved in the process of socialist modernization in China. The trend of sustainable development in many fields, such as economy, environment, culture, and society, has led to the birth of green transportation. Green transportation is a new type of urban transportation system that improves the efficiency of urban transportation, reduces traffic congestion, reduces environmental pollution, and promotes social equity and rational use of resources. Many cities, at home and abroad, have conducted extensive research into the planning and construction of green transportation. Therefore, this study takes green transportation as the guide and conducts data modeling on the impact of urban transportation planning and management measures on the economic development of small and medium-sized cities.

2. Green Transportation

2.1. Concept of Green Transportation. Green transportation is an integrated urban transportation system with the goal of safety, convenience, high efficiency, low pollution, and low energy consumption, which is built with advanced technology and is compatible with human living environment and economic growth. In addition, green transportation is an urban transportation mode based on advanced scientific methods and technologies, considering efficiency and fairness and aiming to establish an urban transportation system that gives priority to public transportation. Therefore, it can effectively promote the harmonious development of urban transportation and ecological environment. At the same time, green transportation is a harmonious transportation

system that aims at reducing traffic congestion, reducing environmental pollution, and promoting the rational use of resources to meet the requirements of sustainable development of urban environment, economy, and society. According to the concept of green transportation system and the different degrees of environmental impact brought by various modes of transportation, the green transportation system can be ranked according to the priority of green transportation, as shown in Figure 2.

There is no uniformity in the research on the concept of green transportation so far. Although different scholars have different understandings of the concept of green transportation, they all share the same concept of sustainable development of urban transportation. From the macroperspective, green transportation should meet the sustainable development needs of urban transportation to the greatest extent possible under various unfavorable external conditions. From the microperspective, green transportation should not only meet individual travel needs, but also minimize transportation energy consumption, maximize resource efficiency, and reduce environmental pollution.

In fact, green transportation is composed of two basic elements, "green" and "transportation." Among them, "transportation" can be understood as the mode of transportation, while "green" indicates the way of development and the requirement of quality. The concept of green transportation corresponds to the theoretical basis of economics such as ecological economics, energy economics, and environmental economics. As a result, in the context of deepening conflicts between economic and social development and resources and environment, green transportation can, to a certain extent, promote a shift in the economic development approach to a sustainable development approach. At the same time, more specific research fields of economics have been created, including green economy, circular economy, low-carbon economy, and ecological economy. What is more, the concepts of green transportation, green cycle, low-carbon transportation, and ecotransportation have also been derived. In summary, the relationship between these green concepts is illustrated in Figure 3.

In the field of economics, green economy is an environmentally friendly and healthy economic approach. Therefore, the essence of green economy is a method of economic development characterized by the preservation of the of human living environment, the reasonable protection of resources, and the promotion of human health. In other words, the core of green economy is the harmonious development of ecology and economy. Low carbon economy is an economic development model that reduces high energy consumption and emphasizes low energy consumption, low pollution, and low emissions. Therefore, the essence of a low-carbon economy is the efficient use of energy and the use of clean energy in the continuous pursuit of economic development. At its core is the innovation of energy-saving and emission reduction technologies. Ecological economy follows the principle of "circular economy" and emphasizes the full potential of natural resources reuse within the carrying capacity of the ecosystem, so as to achieve economic development and environmental protection.

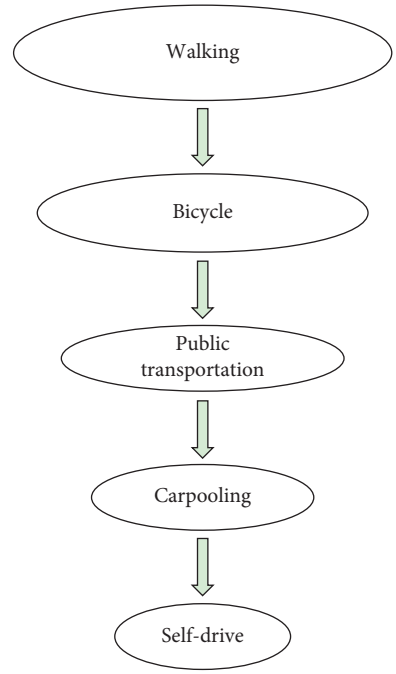

Figure 2: Green transportation system.

2.2. Characteristics of Green Transportation. As a new development concept and the current mainstream development direction of the transportation industry, green transportation is quite different from traditional transportation. First of all, the scope of traditional transportation is much larger than the travel mode of green transportation. In addition, green transportation has a development focus, while traditional transportation does not. For example, green transportation emphasizes and promotes low energy and low pollution travel modes such as walking, bicycling, urban public transportation, and new energy vehicles. However, the development model of traditional transportation is highly arbitrary, as the choice of transportation mode is largely determined by the preferences of individual citizen. In summary, the differences between green transportation and traditional transportation are shown in Table 1.

Green transportation aims to reduce pollution and protect the environment, but it does not restrict the freedom of individuals to travel. On the contrary, the p is not only to achieve the harmonious development of transportation, environment, and economy, but also to make people travel better. First, in the process of developing green transportation, the management and improvement of public transportation can better meet people's demand for quality travel. What is more, in the process of developing green transportation, the government's promotion of green transportation can make citizens aware of the environmental benefits of green transportation. As a result, citizens can willingly choose green transportation. This approach, which ultimately makes citizens willing to choose green transportation, reflects a people-centered approach. Finally, the widespread promotion of green transportation has greatly increased not only the awareness of our citizens to travel green, but also the quality of our citizens. Therefore, the

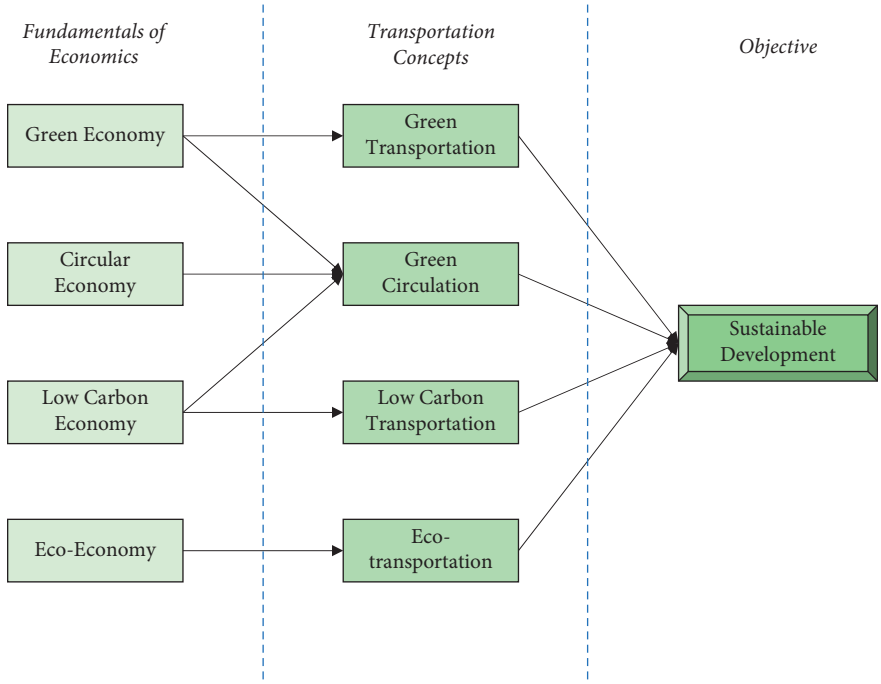

Figure 3: Relationship among concepts related to green economy.

Table 1: Differences between green transportation and traditional transportation.

Development mode	Travel mode	Consumed energy	Amount of consumed energy	Amount of pollution
Traditional transportation	Citizens' choice of travel mode is arbitrary	Oil-based	Much	Much
Green transportation	One of the starting points for citizens' choice of travel mode is energy saving and environmental protection	Clean energy-based	Less	Less

emergence of green transportation is not only a people-oriented approach, but also a win-win situation for the economy, the environment, and the quality of citizens.

3. Economic Effect of the Green Transportation Model

Neoclassical economic theory focuses on physical capital and considers that factors of production move instantaneously between different geographical locations and do not have spillover effects on neighbouring regions. Neo-economic geography, on the other hand, considers the spatial dependence of regional activities and the spatial spillover of capital stocks. For example, product investment or market expansion can lead to costly changes in the income or expenditure of new capital. Changes in a factor of production or an observed attribute in a spatial region can have positive or negative effects on multiple factors in neighboring regions, thus driving the accumulation of capital markets.

3.1. Assumption of the Model. In the economic effect of green transportation model proposed in this research, the following assumptions should be followed:

(1) It is assumed that the impact of domestic force majeure factors on the economic effect of transportation is negligible at the time of the data.

(2) It is assumed that only total sulfur dioxide emissions and total dust emissions are considered as the source of green environmental indicators in the economic effect of green transportation.

(3) It is assumed that roads and railroads occupy an absolute position in the transport infrastructure in the social economy and that other transport infrastructure inputs are not measured.

(4) It is assumed that the spatial section unit is considered as a central point when calculating the spatial section unit distance.

3.2. Autocorrelation Test of Economic Effect of Transportation. The estimation of coefficients becomes complicated when applying the traffic economic effects model regression to analyze the error or lagged terms. This highlights the need for spatial autocorrelation of the model. The description of spatial autocorrelation is reflected in the spatial structure. Therefore, it is not limited to the geographic sense only, where the global correlation statistic only provides a basic

premise and overall description for the spatial autocorrelation of the study, and its correctness is based on the premise of spatial homogeneity.

In determining the spatial correlation of variables among regions, the spatial residual correlation test selected for this study is shown below:

$$\rho = \frac{n}{\sum_{i=1}\sum_{j=1} w_{ij}} \frac{\sum_{i=1}\sum_{j=1} W\left(V_i - \overline{V}\right)\left(V_j - \overline{V}\right)}{\sum_{i=1}\left(V_i - \overline{V}\right)^2}, \quad (1)$$

where ρ refers to the spatial residual correlation, n indicates the number of selected samples, w_{ij} represents the weight matrix, and V_i and V_j refer to the spatial correlation variables.

3.3. Statistical Test of Economic Effect of Transportation. The existing exponential test is a correlation test based on spatial residuals and therefore has poor significance. Therefore, the introduction of Lagrange multiplier statistic with spatial autoregressive effect without spatial residual correlation can be better tested spatially, and its model can be defined as

$$\begin{aligned} H_0&: Y = \alpha \times V + \varepsilon, \\ H_1&: Y = \alpha \times W \times Y + \alpha \times V + \varepsilon. \end{aligned} \quad (2)$$

By constructing the following two LM statistics, this model can be tested and selected. That is, when there is no residual correlation, the model can be tested for the existence of spatial substantive correlation:

$$\begin{aligned} E &= \frac{\left(e'We/m^2\right)^2}{K} \sim \chi^2(1), \\ L &= \frac{\left[e'Wy/\left(ee'/n\right)\right]^2}{Z} \sim \chi^2(1), \end{aligned} \quad (3)$$

where E refers to the LM error, L refers to the LM lag, and

$$\begin{aligned} m^2 &= ee'/n, \\ K &= \left(W^2 + W'W\right)', \\ Z &= \left(W^2 + W'W\right)' + ee'/n. \end{aligned} \quad (4)$$

The LM statistic can only be used to initially judge the model selection by significance. The specific process of spatial autocorrelation test is shown in Figure 4 as a way to determine the final model type.

3.4. Selection of the Model. The spatial social activity network of decision variables is interconnected, and there are mainly the following static spatial models to study the economic effects of transportation (Figure 5). The first one is the spatial autoregressive process of the error term into the traditional effects model of the spatial error model (SEM). The second one is the spatial lag model (SLM), in which the spatial lag term of the explanatory variable is added to the traditional effect model. The third one is the spatial Durbin model (SDM), which means that the spatial lag term of the explanatory variable is added to the SLM to circumvent the endogeneity problem.

3.4.1. Spatial Error Model. The spatial error model implies that the spatial effect between regions is realized through the error term; that is, the economic effect of transportation between regions is stochastic, and the model can be expressed as

$$\begin{aligned} y_{ij} &= \beta \times x_{ij} + \gamma \times c_n + \varepsilon, \\ \varepsilon &= \alpha \times W_\varepsilon + \mu, \\ \mu &\sim N\left(0, \sigma^2 I\right), \end{aligned} \quad (5)$$

where y_{ij} is the explained variable, x_{ij} refers to the explanatory variable, γ indicates the coefficient of the constant term c_n, ε is the error term, and W_ε represents the spatial lag term.

3.4.2. Spatial Lag Model. In the spatial lag model, the explanatory variables in the neighboring regions affect the regions in the system through spatial radiation spillover. Since the SLM model includes the lagged term of the explanatory variables when analyzing the economic effects of transportation, it can be named as a spatial autoregressive model, and its model can be expressed as

$$\begin{aligned} y_{ij} &= \rho \times W \times y_{ij} + \beta \times x_{ij} + \gamma \times c_n + \varepsilon, \\ \varepsilon &\sim N\left(0, \sigma^2 I\right), \end{aligned} \quad (6)$$

where ρ refers to the autoregressive coefficient and $W \times y_{ij}$ denotes the spatial interaction of the proximity region on the explanatory variables of the observed region.

3.4.3. Spatial Durbin Model. When the endogenous interaction effect and the autocorrelated perturbation term cannot reasonably explain the spatial action, a more generalized spatial Durbin model is introduced, incorporating both a spatial error term and a spatial lag model, whose model can be expressed as

$$\begin{aligned} y_{ij} &= \rho \times W \times y_{ij} + \beta \times x_{ij} + \eta \times W \times x_{ij} + \gamma \times c_n + \varepsilon, \\ \varepsilon &\sim N\left(0, \sigma^2 I\right). \end{aligned} \quad (7)$$

In the spatial lagged and spatial Durbin models, the explanatory and explained variables appear spatially correlated. In view of the above theories, this paper applies MLE for effect analysis to the measurement of spatial panel data.

3.5. Case Study. Given the impact of feedback effects on the transport infrastructure stock indicators, especially their first-order lagged term regression coefficients, Table 2 looks at the short-term effects and long-term effects, respectively. Specifically, this study deeply explores the decomposition of green transportation economic effects of provincial transportation infrastructure stock indicators in China through the effect decomposition of dynamic spatial Durbin model.

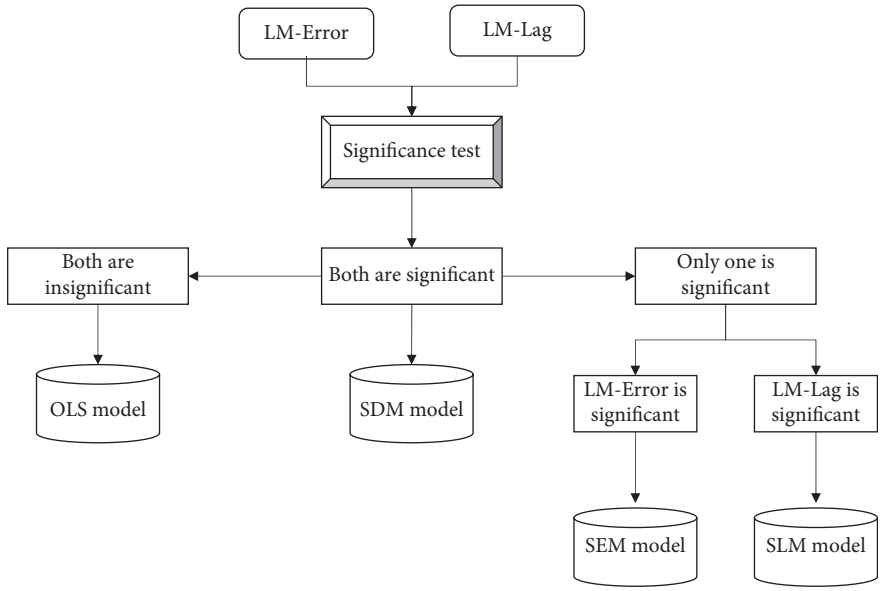

Figure 4: Process of selecting model.

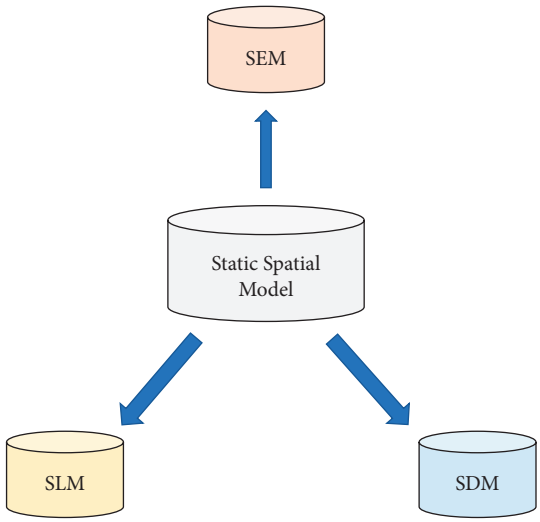

Figure 5: Various static spatial models.

Table 2: Result of spatial Durbin model.

	Road	Highway	Railway	GDP	Population
W_1	0.05	46.72	98.71	0.02	0.07
W_2	−0.48	123.21	431.82	0.38	0.14
W_3	0.12	47.78	1.23	0.16	0.06
W_4	0.03	66.89	12.56	0.67	0.01

The effect decomposition values of the stock indicators verify the robustness of the coefficient estimation results. The significance level of each weight matrix under fixed effects is higher than that of random effects, and the transport infrastructure stock indicators are significant under both the adjacency matrix (W_1) and the economic matrix (W_4), which verifies the validity of the coefficient estimation and effect decomposition measures. By comparing the short-term and long-term effects of the stock indicators under each weight matrix, it is clear that the short-term effects of most of the explanatory variables are more significant at the 1% significance level, and the economic matrix is more significant. Therefore, this indicates that, under the global development situation of green transportation and the policy guidance of China's strong transportation country, the long-term effect of transportation infrastructure investment in the green economic growth of each province is poor. In the process of physical capital accumulation, the indirect effect is obvious under each weight matrix, and the contribution of transportation infrastructure stock indicators gradually increases in prominence under the economic weight. This verifies that the green transportation economic effect of transportation infrastructure inputs is inherent as a direct carrier of production factors circulation in the capital market and regional network structure.

4. Conclusion

The results of this study show that the green transportation economic effects of various types of transportation infrastructure inputs are uneven. Specifically, the trend of transportation infrastructure inputs contributing to green total factor productivity growth in the region is slowing down. In the process of investment, the negative effect of pollution emission of various transportation infrastructure modes on green transportation economy is gradually increasing. Therefore, the green transportation economy effect of transportation infrastructure investment should be considered as a priority in the early stage of transportation planning, increasing, at the same time, the density of highway and railroad. The positive externality of the green transportation economic effect should be fully incorporated into transportation infrastructure investment. In addition, this paper defines green transportation as an urban

transportation system that uses new energy and energy-efficient means of transportation for the purpose of achieving sustainable social development. As a result, the basic requirement of green transportation is to achieve the long-term development of urban transportation. The essence of green transportation is to establish a sustainable transportation system that can meet the transportation needs of residents while saving energy and protecting the ecological environment. In other words, green transportation can meet the largest social transportation needs with the least energy consumption and environmental impact and achieve the coordinated development of transportation, environment, and economy.

The study of urban green transportation development is a systematic project. Due to time constraints and personal knowledge accumulation, this paper only focuses on the economic impact of urban green transportation. Therefore, the research is not deep enough, and there are still some problems that need further research. The matching degree of the weight matrix selection in this paper needs to be verified in depth. If possible, all types of spatial weight matrices should be experimented in the future to select the optimal spatial weight matrix.

Data Availability

The labeled data set used to support the findings of this study is available from the corresponding author upon request.

Conflicts of Interest

The authors declare that there are no conflicts of interest.

Acknowledgments

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