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Research Article

Traffic Structure Optimization in Historic Districts Based on Green Transportation and Sustainable Development Concept

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To perform the reasonable traffic structure in the historical districts and effectively alleviate the contradiction between limited traffic supply and rapid growth of the traffic demand in historical districts, a dynamic game model of traffic competition is established in this paper, aiming at the green transportation and sustainable development. Firstly, the logit model reflecting the sharing rate of the traffic mode is established by using the generalized cost method to quantify all the factors that influence the travel mode selection. Accordingly, a dynamic game model of complete information is established for the trip mode of historical districts, taking into account the economic sustainability, environmental sustainability, and social sustainability of the traffic development. The model is based on the goal of maximizing the generalized profit, and modeling with environmental pollution, energy utilization, and road service level as the common constraints of various traffic modes. By iterating the Nash equilibrium solution of the model, the optimal structure and the optimal share of the traffic modes in the historical districts can be predicted. Finally, the model presented in the study is verified by the historical districts of Academy Street in Zhengzhou city, China, and the optimal structure and optimal traffic share of each traffic mode in the block are obtained. By changing the constraint conditions of the model, two sets of different governance policies are compared and analyzed, and some feasible suggestions on improvement of traffic structure are also put forward. The research results can be the important reference for traffic planning in historic districts.

1. Introduction

Historical districts refer to the important positions in the history and culture of a certain area, representing the cultural context of the region and the building group reflecting regional characteristics [1, 2]. Presently, there are three major contradictions in the transportation development of historic cities [3–7]. The first one is the relationship between the development of historic cities and the current level of transportation services, the second contradiction is the relationship between the growth of the total traffic demand and the limited supply of the city, and the relationship among the reconstruction, extension, and style protection of historic urban infrastructure is the third contradiction. Therefore, any planning and construction activities in historic cities should and must give priority to historical and cultural protections. Modern cities, however, continue to suffer a vicious circle of traffic congestion which is formed by inappropriate traffic management measures. Meanwhile, a lot of resources are consumed in this process, and the historic city landscape and ecological environment are severely damaged, resulting in that the ecological environment and transportation system are on the brink of collapse. Therefore, how the inadequate transportation supply meets the ever-increasing trend of total traffic demand and structural diversification, realizing a new balanced supply-demand relationship, has become an urgent issue to be resolved. With a certain amount of traffic travel demand and difficulty in the road reconstruction and expansion, a rational traffic structure based on the concept of sustainable development should be established for the historic city. To enhance the proportion of high-efficiency, low-energy, low-pollution, and high-capacity modes of transportation in residential travel, its role in solving urban traffic problems should be more lasting and effective than blindly expanding the supply of transportation. Moreover, it can also realize the harmonious development of human society and natural environment.

The existing research on urban traffic structure mainly involves four aspects. The first research aspect is the development mode of urban spatial layout and traffic structure [8–11]. At present, according to the national conditions of various countries and the experience of urban transport mode development, scholars put forward four urban transport development modes. The first mode is to advocate the full development of car travel. They advocate the decentralized development of the city, the decentralized function of the city center, long-distance travel as the main mode, and typical cities such as Los Angeles and Detroit. The second mode is o suggest that the public transport system and car traffic should be the common subject, and the sharing rate of the two is similar. Cities develop in a high density and centralized way and maintain a strong city center function. Traffic networks consist of powerful radial roads and loops close to the city center and typical cities such as Paris and Tokyo. The third mode advocates rail transit as the backbone of public transport, restricting car travel and retaining the function of the city center. Meanwhile, different levels of decentralized centers will be established to minimize the demand for residents to travel, such as Singapore, Stockholm, and other typical cities. The fourth mode is to advocate that the car should be taken as the main travel mode, and the public transport is taken as the supplement travel mode. Urban road and rail networks are radial. The function of urban centers will be restricted. To a certain extent, the role of the city center is retained and the development of suburban centers is encouraged, such as San Francisco, Melbourne, and other typical cities. From the abovementioned concept, it can be seen that the urban spatial layout is closely related to the development mode of traffic structure, and different urban spatial layout will produce a completely different traffic development mode. Recently, international consensus has been reached on giving priority to the development of public transport to improve urban traffic conditions. However, according to the characteristics of different urban layouts, the specific proportion of different modes of transportation in urban residents travel still needs further study. The second research aspect is the relationship and its model between urban land use and traffic structure. As Ewing et al. [12] pointed out, if the arrival and destination of urban residents are considered, there is a strong correlation between choice of the transportation mode and the urban form. Under the conditions of land use in different cities, the choice of transportation modes for residents to travel is very different. Kakaraparthi and Kockelman [13] used UrbanSim simulation software to simulate the interactive relationship between urban traffic structure and land use system in Austin, Texas, USA, which can respond to the situation environment. Yigitcanlar and Dur [14] proposed a model (SILENT) to evaluate the sustainable development of urban land use, environment, and transportation. Overall, international studies have reached a consensus on the impact of urban spatial distribution and land use on travel choice. Employing qualitative and quantitative methods, scholars synthetically analyzed the relationships among the urban land use intensity, population, housing, employment, and other factors, as well as the impact of various factors on vehicle travel rate and distance. Moreover, according to the development process and characteristics of urban land use and traffic structure, scholars put forward different urban traffic structure proposals from the perspective of land use on the basis of studying traffic structure, urban form, population density, and urban scale. In recent years, the optimization model of land use and traffic structure has been established in the world. The optimization model based on different objectives has been applied in traffic structure planning. For the third aspect, researches on the optimization model and method of urban traffic structure are conducted unceasingly. Based on the previous research results, the optimization model of urban traffic structure can be basically established from the following three ways. Firstly, according to the government public choice and the resident individual choice, the advantages and disadvantages of various modes of transportation are analyzed, and the urban traffic structure is optimized [15]. Secondly, the urban traffic structure can be optimized by focusing on unilateral development needs. Some scholars choose to optimize the commuting mode based on the reliability of travel time, such as William et al. [16], who studied the reliability of travel time and the impact of stopping time on traffic patterns, and put forward suggestions for optimizing commuting patterns. Meanwhile, from the perspective of low-carbon environmental protection, or based on cost and utility goals, many scholars have carried out traffic structure optimization research [17–19]. Thirdly, from the macro perspective, according to the urban sustainable development needs, the optimization model of urban traffic structure can be established considering the constraints of economy, society, resources, and environment. For instance, under the sustainable development transportation planning theory system, the concept of traffic capacity, environmental capacity, and mode energy consumption were presented by Wang et al. [20], and the optimization model of urban traffic structure based on energy consumption was proposed accordingly, which can guarantee the reasonable traffic structure with minimum energy consumption to meet the traffic demand. Aiming at the sustainable development of urban traffic, Lu and Wang [21] proposed the structural optimization principle of the passenger traffic in an urban traffic system. According to the development courses and characteristics of urban land use and traffic structure, different urban traffic structure suggestions from the perspective of land use were put forward based on the study of traffic structure, urban form, population density, and urban scale. Throughout the existing research, the traffic structure optimization model based on different objectives has also been applied in the planning practice, but the determination and selection of relevant factors are still hypothetical. Some constraints of the model have not been fully quantified, and the corresponding factors need to be further analyzed. Lastly, researches on the competition and transformation of public transport and private transportation. For example, Prato et al. [22] compared public transport and private transport in Copenhagen Region when traveling short distance and established a differential equation model of traffic competition under the restriction of urban transport ecological carrying capacity. Tabuchi [23] studied the competition between the two modes of transportation under different charging systems. Based on analyzing the influencing factors of rail transit and bus traffic attraction, Mark and Vladimir [24] built a competition model between rail transit and regular bus. Eriksson and Nordlund [25–27] studied two traffic policies that increased fuel taxes and increased public transport services. The effect of two policies on reducing the use of cars was not significant. But when the two policies were implemented in combination, the effect would be more significant.

Overall, the study of traffic structure almost begins with the rapid development of urban motorization, which mainly focuses on the study of the relationship between land use and traffic structure, the optimization model of traffic structure, and the transformation strategy of different traffic modes. Additionally, the practical experiences of traffic management measures such as congestion pricing are investigated according to the specific application of cities in various countries. Quantitative analysis shows that the optimization model based on different objectives has been applied in traffic structure planning practice, but the determination and selection of relevant factors and model constraints are not comprehensive enough. Meanwhile, for the study of traffic structure, the subject investigated is more focused on conventional cities. At present, more and more attention has been paid to the traffic problems in historic urban areas, but few studies have been devoted to the traffic structure of historic urban areas. If the traffic structure optimization model is established directly without considering the road conditions, environmental pollution, protection and restriction of energy utilization, and traffic characteristics of historic districts, the calculation result of the model is unreasonable and cannot effectively improve the traffic environment of historical urban areas. According to the traffic characteristics and protection restrictions of historic urban area, by studying the reasonable traffic structure of historic urban area, the most effective use of urban traffic resources can be realized and the overall function and function of urban traffic system can be maximized. Moreover, most of the existing studies use multivariate linear mathematical models to establish in depth and accurate models for traffic structure optimization. The multivariate linear mathematical model, however, cannot reflect the coordination and competition relationships among traffic modes. Furthermore, because there are no obvious monetary expenditure characteristics such as fare and fuel charges, the existing models usually do not consider the two types of traffic, pedestrian and bicycle, or simply quantify the cost of these two types of traffic. Game theory, which studies the coordination between rational subjects, has become one of the standard analysis tools of economics and extensive applications in biology, economics, international relations, computer science, political science, military strategy, and many other disciplines. Meanwhile, the relationship between the travel modes in the historic district meets the basic elements of the game, and it is very suitable for describing with a noncooperative game under complete information. By solving the Nash equilibrium solution, the competition behavior between transportation modes can be obtained; moreover, under their own conditions and market demand conditions, the strategy set can be achieved when the game players maximize their interests. Therefore, considering the actual traffic situation, environment, and road constraints, the concept of generalized cost is proposed, and the impacts of travel factors on the travel cost of each transportation mode are quantified in the unified way, which can enrich the theory of traffic structure research.

2. Urban Traffic Sustainability Analysis and Assessment

In the past two decades, the concept of sustainable development of urban passenger transport has aroused great interest of researchers and practitioners. On the one hand, scholars actively study the connotation, basic concepts, main contents, performance characteristics, and development strategies of sustainable development of the urban passenger transport system. For example, Tara and Josias [28] discussed the concept of sustainable transport, summarized several different views on the definition, application, and value of the sustainable transport, and discussed the key issues related to the sustainable transport and how to understand and apply it. On the other hand, the evaluation of the sustainable development of the urban transport system has become a research hotspot with mature research results being presented [29–31]. Especially, the evaluation investigation on the coordinated relationships between urban transport and land use, urban transport and ecological environment, and urban transport and economic development are very sufficient. According to different research contents, researchers put forward a variety of urban traffic sustainable development evaluation system framework and classical evaluation methods. For example, many evaluation methods, including AHP (analytic hierarchy process) [32], Fuzzy TOPSIS [33], fuzzy logic method [34], factor analysis method, fuzzy comprehensive evaluation method, comprehensive evaluation method [35], data envelopment analysis, and machine learning method based on neural network, are employed for comprehensive evaluation. Meanwhile, on the premise of traffic sustainability, many traffic sustainable optimization models and implementation policies based on different levels are proposed. For example, Yoshino et al. [36] proposed the environmental efficiency model (EEM), which measures the energy consumption efficiency of each transportation system at a given moving level by introducing some feasible conditions, providing a feasible transportation energy consumption target for each city. It is suggested that we should improve energy efficiency through technological innovation and establish emissions trading systems between developed and developing countries to achieve environmentally sustainable transport. Aiming to support the sustainability of the transport system, Konstantinos et al. [37] proposed a quality management system for mobility management (QMSMM) to help cities systematically formulate and deploy mobility management plans and management measures. To ensure that the city has the financial resources and institutional capacities to maintain the share of public transport, Dhar and Shukla [38] proposed sustainable low-carbon transport (SLCT) schemes based on sustainable development strategies, advocating reform at the urban level, which can improve transport structure, reduce demand, and shift demand to a more sustainable mode. Zhou [39] proposed a multilinear traffic structure optimization model for Chinese cities from the perspective of land use, aiming at the sustainable development of urban traffic. The existing optimization models can provide references for the theoretical models of traffic planning in historic urban areas, whether in the establishment of influence factors or the setting of constraint conditions. Furthermore, in recent years, with the maturity of research and practice, several feasible measures for sustainable development of transportation are put forward drawing on the successful experience. For instance, Fwa and Ang [40] pointed out that Singapore takes the lead in using economic means to manage the traffic demand. More specifically, Singapore has achieved sustainable urban transport through the implementation of urban road toll system, highway electronic toll system, and vehicle quota system. Mörtberg et al. [41] highlighted the sustainable transport policy of Stockholm and established the LEAM Model. The sustainability of urban development policy in Stockholm was assessed. In the case study, two scenarios of Stockholm's future urbanization were analyzed, indicating the impact of different scenarios on ecological priorities, which can help policymakers to examine the future direction of urban development more comprehensively. Meanwhile, scholars generally believe that congestion pricing can be employed as an effective measure of traffic demand management to control the individual motor traffic demand so as to transfer urban traffic structure to public transport and improve the overall operational efficiency of urban transport [42–44]. At present, many cities have adopted congestion pricing strategies to regulate traffic demand in some areas or roads to varying degrees, such as Singapore, London, Stockholm, and Toronto. Among them, the urban traffic congestion charges, which were implemented in London in 2003, had the greatest impact, as shown in Figure 1 (the data in the figure are from the London travel report [45]). Due to the successful implementation of congestion pricing policy in London, scholars are increasingly studying congestion pricing. However, due to the wide influence of traffic congestion pricing, involving the interests of all aspects of adjustment, all kinds of adverse effects cannot be fully predicted in advance; therefore, the city should take a very cautious attitude in the implementation of congestion pricing strategy.

Furthermore, other widely advocated policies for urban sustainable transport include attaching importance to the integrated planning of transportation and land use, implementing the strategy of giving priority to public transport, improving the rationality of road network construction, improving the parking planning and charging system, and calling on citizens to save energy, protect the environment, and change the travel modes [46–48]. Among them, traffic optimization measures, including implementing bus priority, changing the way of public travel, and standardizing the roadside parking system, can provide valuable experience for the improvement of traffic in historic districts. From the abovementioned, the research on the sustainable development of the urban transportation system has been relatively mature with many instructive research results being presented, especially for the evaluation of the coordinated relationships of the urban traffic between the coordinated management of land use, the sustainable development of the ecological environment, and the urban economic development. It should be noted that, in these relatively mature research fields, most of the research objects are the centers of megacities or developed cities. The investigations on the sustainable development of historical blocks in developing cities are still rarely reported.

3. Establishment of Competitive Game Model for Travel Modes in Historic Districts

From the perspective of travelers, they pay for financial, physical, and energy expenses to purchase a travel service that suits them. When making travel decisions, travelers will choose the most cost-effective travel mode between cost and getting services according to their own needs. From the perspective of travel modes, the income amount depends on the costs paid by the traveler and the costs of the self-disbursement, assuming that there are M types of travel modes in the district passenger transport system and attracting customers by adjusting their own comfort (S_m), rapidity (V_m), convenience (F_m), safety (A_m), and economical (C_m) strategies. To obtain greater benefits for various travel modes, strategies are needed to continuously adjust strategies according to competitors' circumstances. Obviously, this game process is balanced when the average person in each participant gets the best benefit, and each trip mode reaches the optimal share.

3.1. Generalized Cost Model. Since the influencing factors of the generalized costs are not of the same dimension, the concept of time value is utilized in the study to quantify the influencing factors. Equation (1) expresses the time value [49]:

$$\overline{v} = \frac{\text{GDP}}{N \times A}, \tag{1}$$

where $\overline{v}$ is the time value of travelers in the area (dollar/person-h) and GDP is the gross domestic product of the region (dollar). N is the total population of a city in the base year, and A is the average working time, which can be calculated by using fifty working weeks per year, five working days per week, and eight working hours per working day.

(1) Economic index C_{mij} refers to the total costs of travelers' access to door-to-door services, which can be calculated by the following equation:

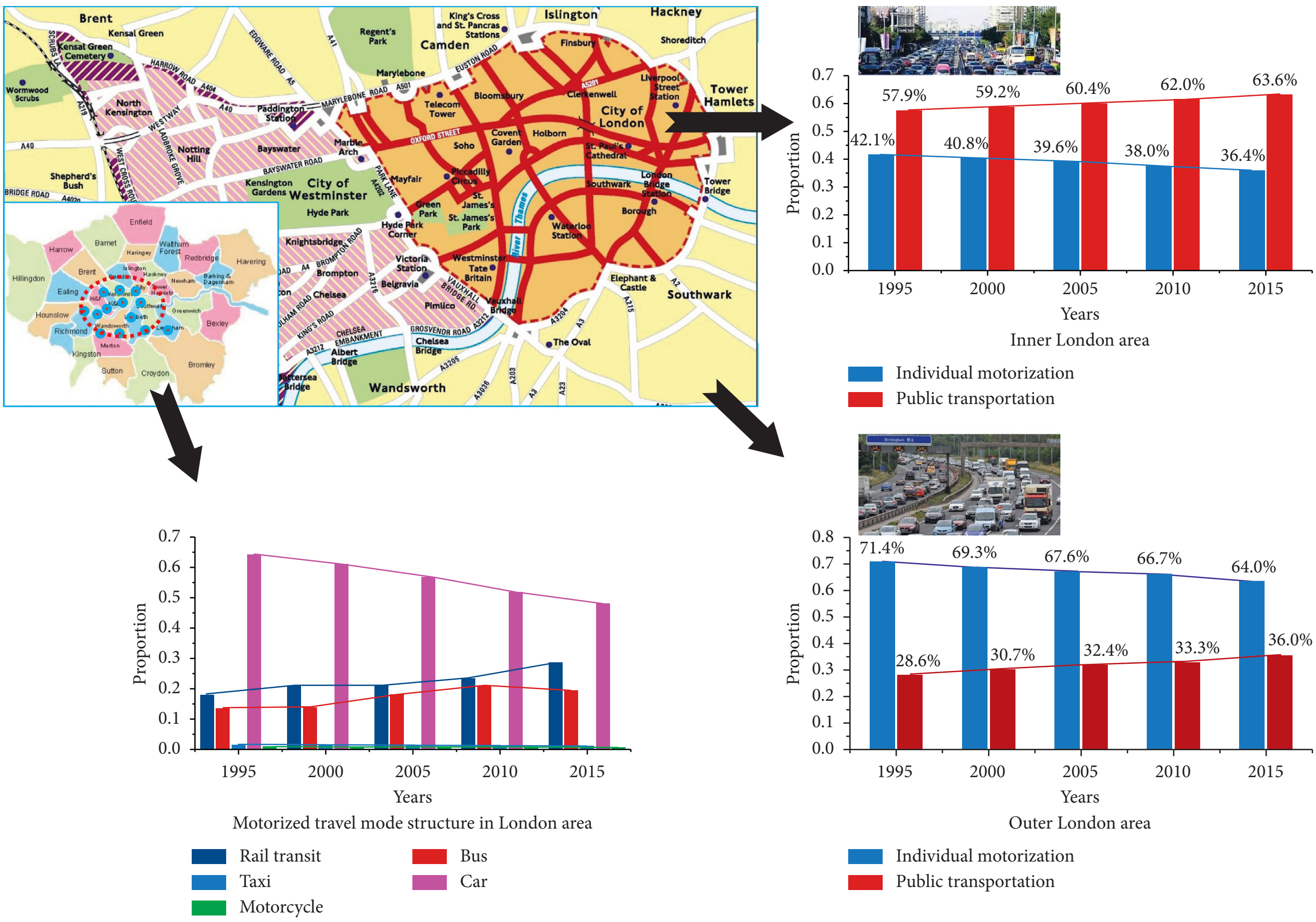

Figure 1: The distribution of the traditional elements in the Academy Street [45].

$$C_{mij} = a_{mij} \times L_{mij}, \quad (2)$$

where C_{mij} represents the generalized costs of the m types of the travel mode between the traffic area i and the traffic area j (dollar/man), a_{mij} is the fare rate (dollar/man-km), and L_{mij} is the travel distance (km).

(2) Rapidity index V_{mij} is measured by the value of time consumed according to the traffic travel activities. The fee can be expressed as follows after the distance L_{ij} being determined:

$$V_{mij} = \frac{L_{mij}}{v_{mij}} \times \overline{v}, \quad (3)$$

where V_{mij} is the generalized cost (dollar/man) of the rapidity from the traffic area i to the traffic area j, L_{mij} is the travel distance (km), and v_{mij} is the driving speed (km/h). $\overline{v}$ is the time value of the passenger (dollar/man-h).

(3) Convenience F_{mij} refers to the convenience of travelers choosing a transportation mode. The measured index is the value of all time consumed except the travel time, which can be calculated as follows:

$$F_{mij} = \overline{v} \times E_{mij}, \quad (4)$$

where F_{mij} is the convenient generalized cost (dollar/man) between traffic area i and traffic area j and E_{mij} is all time spent except the running time (h). $\overline{v}$ is the time value of travelers (dollar/man-h).

(4) Comfort S_{mij} is the subjective feeling of the traveler's comfort to the service provided. In this paper, the fatigue recovery time after completing the trip is used to quantify the comfort, which can be expressed as follows [50]:

$$S_{mij} = g_{mij}(t) \times \overline{v} = \frac{\overline{v} \times R_{t\max}}{\left[1 + \delta_{mij} \times \exp\left(-\rho_{mij} t_{mij}\right)\right]}, \quad (5)$$

where S_{mij} is the generalized costs of comfort from traffic area i to traffic area j (dollar/man), $R_{t\max}$ is the ultimate fatigue recovery time (h), t_{mij} is the running time of OD by the travel mode m, δ_{mij} is a quantitative parameter for the vehicle running environment, ρ_{mij} is the fatigue recovery time intensity factor ($1/h$), $\rho_{mij} > 0$, and $\overline{v}$ is the time value of the passenger (dollar/man-h).

(5) Safety A_{mij} refers to the travelers' evaluation of the safety services provided by the travel mode, which

usually describes the travel safety by the safe travel distance. It can be calculated from the following equation:

$$A_{mij} = L_{mij} \times \gamma_m \times W_m, \quad (6)$$

where A_{mij} is the generalized cost of the safety from the traffic area i to the traffic area j, L_{mij} is the running distance (km), γ_m is the average accident rate of the traffic mode M (time/km), and W_m is the average economic loss of a traffic accident in the traffic mode m (dollar/man-time).

In summary, general travel costs paid by the traveler choosing the travel mode m can be calculated as follows:

$$P_{mij}\left(C_{mij}, V_{mij}, F_{mij}, S_{mij}, A_{mij}\right) = C_{mij} + V_{mij} + F_{mij} + S_{mij} + A_{mij}. \quad (7)$$

3.2. Construction of Noncooperative Dynamic Game Model for Travel Mode in Historic Districts

3.2.1. Traveling Mode of Generalized Profit Model. In a certain period of time, the total travel demand Q_T in the districts is exogenous, which means that the share Q_m of the travel mode m depends not only on its own competitive strategy portfolio Ω_m but also on other combinations of competitive strategies. Thus, for a traffic mode m, the amount of traffic shared can be calculated as follows:

$$Q_m = Q_T \cdot M_m(\Omega_m), \quad (8)$$

where Q_m is the transportation demand of the transportation mode m and $M_m(\Omega_m)$ is the market share of the traffic mode m, which is a function of the competition strategy Ω_m ($\Omega_m = C_m, V_m, F_m, S_m, A_m$) of the traffic mode m.

The logit model is a commonly used nonaggregate selection model; in this paper, the market share of the traffic mode is described by using the logit model, and the benefit function of the model is defined by using the generalized cost [51–53]. After comprehensively considering the influencing factors of the mode selection, the following equation can divide the travel mode m from the traffic area i to j:

$$M_{mij}\left(\Omega_{mij}\right) = \frac{\exp\left[-\theta\left(\alpha_m S_{mij} + \beta_m V_{mij} + \gamma_m F_{mij} + \mu_m A_{mij} + \omega_m C_{mij}\right)\right]}{\sum_m \exp\left[-\theta\left(\alpha_m S_{mij} + \beta_m V_{mij} + \gamma_m F_{mij} + \mu_m A_{mij} + \omega_m C_{mij}\right)\right]}, \quad (9)$$

where θ is the random taste coefficient of the model, $\alpha_m, \beta_m, \gamma_m, \mu_m$, and ω_m are the weight of influencing factors such as comfort, rapidity, convenience, safety, and economy.

For the user demand of a certain OD pair within a district, it can be known that the user demand for the m mode of traveling between the traffic area i to j can be calculated by the following equation:

$$Q_{mij} = Q_{Tij} \times \frac{\exp\left[-\theta\left(\alpha_m S_{mij} + \beta_m V_{mij} + \gamma_m F_{mij} + \mu_m A_{mij} + \omega_m C_{mij}\right)\right]}{\sum_m \exp\left[-\theta\left(\alpha_m S_{mij} + \beta_m V_{mij} + \gamma_m F_{mij} + \mu_m A_{mij} + \omega_m C_{mij}\right)\right]}. \quad (10)$$

Therefore, the general profit π_m of traffic demand for the travel mode m can be calculated by

$$\pi_m = \sum_i^n \sum_j^n \left[P\left(S_{mij}, V_{mij}, F_{mij}, A_{mij}, C_{mij}\right) \times Q_{Tij} \times \frac{\exp\left[-\theta\left(\alpha_m S_{mij} + \beta_m V_{mij} + \gamma_m F_{mij} + \mu_m A_{mij} + \omega_m C_{mij}\right)\right]}{\sum_m \exp\left[-\theta\left(\alpha_m S_{mij} + \beta_m V_{mij} + \gamma_m F_{mij} + \mu_m A_{mij} + \omega_m C_{mij}\right)\right]} - U_{mij} \right], \quad (11)$$

where U_{mij} is the operating cost of the travel mode m between i and j in traffic area, which is obtained through traffic investigation.

3.2.2. Historic Districts Traffic Constraints. Various travel modes in the historic district can be used to increase market share through various competition strategies. To achieve sustainable development of the traffic structure in the neighborhood, the increase in the occupancy rate of various modes should be limited by the appropriate traffic volume $Q_{m\max}$ ($Q_m \le Q_{m\max}$) of the travel mode. In addition, the sum of the share of all travel modes is not greater than the total demands $Q_T(Q_T = \sum_{i=1}^n \sum_{j=1}^n Q_{Tij}(\sum Q_m(\Omega_m) \le Q_T))$ of residents in the area.

To maintain and improve the traffic status of historical districts, the environmental factors and social factors of sustainable development should be taken into account in the limiting of travel volume, which should not exceed the limits of environmental pollution and energy using limits and also the service level of roads in historic districts should also be taken as a constraint.

(1) Limit Value of Vehicle Traffic Environmental Pollution. Utilizing the ground concentration standard for pollutants defined in the ambient air quality standard GB3095-2012 as limit, the following equation for calculating the total allowable emissions of traffic pollutants in the street blocks can be established according to the theoretical box model:

$$\mathrm{UTEC_g} = \left[\frac{\left(C_g \times \mu \times h\right)}{\sqrt{s}}\right] \times s \times T \times \alpha, \quad (12)$$

where $\mathrm{UTEC_g}$ is the allowable emission limit (mg) for class g pollutants within T, α is the sharing rate of traffic emission (%), s is the urban area (m^2), T is the time of the control cycle (h), C_g is the ground concentration limit for pollutants of class g (mg/m^3), μ is the dominant wind speed (m/s), and h is the height of the mixed layer (m):

$$\sum_{i=1}^n \sum_{j=1}^n \sum_k \rho_{kg} \times Q_{kij} \times L_{kij} \le \mathrm{UTEC_g}. \quad (13)$$

The limit model of motor vehicle traffic can be established by Equation (13), Q_{kij} is the traffic volume of category k motor vehicles between i and j in the traffic area (veh), L_{kij} is the average distance traveled between the traffic area i to j using the category k motor vehicles (km), and ρ_{kg} is the g-type pollutant emission factor of a class k motor vehicle (mg/veh · km).

(2) Limit Value of Vehicle Traffic Energy Utilization. Considering the close correlation between various energy consumption and traffic pollution in cities, environmental capacity should be used as a constraint. At the same time, to achieve the green development of traffic, the traffic volume of motor vehicles should be strictly controlled. The limiting model of total traffic and energy utilization in historical districts can be established by

$$\sum_{i=1}^{n}\sum_{j=1}^{n}\sum_{k}\mu_k \times \eta_{kij} \times Q_{kij} \times L_{kij} \le E_{\max}, \tag{14}$$

where μ_k is the energy consumption of class k motor vehicles (MJ/person · km), η_{kij} is the average passenger capacity of category k motor vehicles between i and j in traffic areas (person/veh), and $E_{\max}$ is the upper limit of energy consumption (MJ) shared by passenger traffic in historic districts. The value is taken as the energy consumption limit for sustainable development which is required to ensure travel [54, 55].

(3) Traffic Volume Limit Based on Road Network Service Level. Most of the roads in the historic districts are narrowed and restricted, but the traffic demand is huge, leading the current network level of the historic districts worse than that of other areas in the city. The traffic volume constraints based on the road network service level are more conducive to the smooth operation of the district traffic than that based on time and space consumption. To ensure the sustainable development of the traffic in the district, the implementation of traffic management must ensure that the road network in the historical districts can achieve a certain service level. In the road network of historical districts, the V/C ratio, which is commonly used internationally, can be employed to reflect the road network service level. Therefore, the total traffic limiting model based on road network service level can be established by

$$\begin{aligned}\sum_{i=1}^{n}\sum_{I=1}^{n}\sum_{k}Q_{kij} &\le \sum_{i=1}^{n}\sum_{j=1}^{n}\sum_{I=1}^{4}K(I)\times L(I)\times \mu(I)K(I)\\ &= \frac{\lambda_0 \times C_0(I)}{U_0(I)\times(1-0.94\lambda_0)},\end{aligned} \tag{15}$$

where I is the road class, which can be divided into expressway, main road, secondary road, and branch road according to the road grade, $K(I)$ is the traffic density when the service level of the road network reaches λ_0, $L(I)$ is the total number of kilometers of the road with the class I, and $\mu(I)$ is the comprehensive utilization factor of space-time resources for the road with class I. $C_0(I)$ is the design traffic capacity of road with the class I. $U_0(I)$ is the design speed of the road with class I.

The constraints on the traffic volume of motor vehicles take the minimum value among the environmental traffic pollution limits of motor vehicles, the traffic energy utilization limits, and the traffic volume based on road network service levels. It is difficult to determine the service level of the road network by the traffic volume of nonmotorized vehicles and pedestrians. Therefore, the traffic volume limit is determined based on the principle of "time-space consumption."

3.2.3. Construction of the Game Model. The competition among different travel modes in the historic districts is a game process, in which both of them can maximize their own interests under the constraints of their own conditions and market requirements. Each travel mode is treated as a participant with bounded rationality, and the game goal is to maximize the profit of their respective broad sense. The constraint conditions are the limit traffic volume at the peak hour of each transportation mode under the premise of protecting the features of the historic districts. Therefore, the noncooperative dynamic game model of the travel modes in historic districts can be established by

$$\left\{\begin{aligned}&\max\pi_m = \max\sum_{i}^{n}\sum_{j}^{n}\Bigg[P\left(S_{mij}, V_{mij}, F_{mij}, A_{mij}, C_{mij}\right)\times Q_{Tij}\\ &\quad\times\frac{\exp\left[-\theta\left(\alpha_m S_{mij}+\beta_m V_{mij}+\gamma_m F_{mij}+\mu_m A_{mij}+\omega_m C_{mij}\right)\right]}{\sum_m \exp\left[-\theta\left(\alpha_m S_{mij}+\beta_m V_{mij}+\gamma_m F_{mij}+\mu_m A_{mij}+\omega_m C_{mij}\right)\right]}\\ &\quad-U_{mij}\Bigg],\\ &Q_m(\Omega_m)\le Q_{m\max},\\ &\sum_k Q_k(\Omega_k)\le Q_{k\max},\\ &\sum Q_m(\Omega_1,\ldots,\Omega_i,\ldots,\Omega_N)\le\sum_{i=1}^{n}\sum_{j=1}^{n}Q_{T_{ij}}.\end{aligned}\right\} \tag{16}$$

4. Nash Equilibrium Solution for the Travel Modes' Competition Model in Historic Districts

4.1. Existence Condition of Nash Equilibrium Solution. In a strategy combination, Nash equilibrium means that everybody's strategy at this time can get the maximum benefit without others changing the strategy. Therefore, based on the structure of the Nash equilibrium model, the competition model of the passenger transport market in the districts can be established. In other words, the optimal sharing amount for each travel mode should satisfy the following inequality group as

$$\left\{\begin{array}{c}\max\pi_1\{\Omega_1,\ldots,\Omega_M\}, Q_1\{\Omega_1,\ldots,\Omega_M\}\le Q_{1\max},\\ \vdots \\ \max\pi_m\{\Omega_1,\ldots,\Omega_M\}, Q_i\{\Omega_1,\ldots,\Omega_M\}\le Q_{m\max},\\ \vdots \\ \max\pi_M\{\Omega_1,\ldots,\Omega_M\}, Q_m\{\Omega_1,\ldots,\Omega_M\}\le Q_{M\max}.\end{array}\right\} \tag{17}$$

To calculate the model, the Lagrange multiplier $L_m(\Omega_1,\ldots,\Omega_m)$ is utilized into the model, and the following equation is obtained [56, 57]:

$$\begin{aligned} L_m(\Omega_1,\cdots\Omega_m,\cdots\Omega_M) &= \pi_m\{\Omega_1,\ldots,\Omega_m,\ldots,\Omega_M\}\\ &\quad + \lambda_m\left[Q_{m\max} - Q_m\{\Omega_1,\ldots,\Omega_m,\ldots,\Omega_M\}\right]. \end{aligned} \tag{18}$$

Therefore, under the current conditions, the optimal solution $\Omega_m^* = (C_m, V_m, F_m, S_m, A_m)$ of the mth travel mode must satisfy the following condition:

$$\begin{array}{l}\left\{\begin{array}{l}\dfrac{\partial}{\partial S_m}L(\Omega_1^*,\ldots,\Omega_m^*,\ldots,\Omega_M^*)=0,\\[2ex] \dfrac{\partial}{\partial V_m}L(\Omega_1^*,\ldots,\Omega_m^*,\ldots,\Omega_M^*)=0,\\[2ex] \dfrac{\partial}{\partial F_m}L(\Omega_1^*,\ldots,\Omega_m^*,\ldots,\Omega_M^*)=0,\\[2ex] \dfrac{\partial}{\partial A_m}L(\Omega_1^*,\ldots,\Omega_m^*,\ldots,\Omega_M^*)=0,\\[2ex] \dfrac{\partial}{\partial C_m}L(\Omega_1^*,\ldots,\Omega_m^*,\ldots,\Omega_M^*)=0,\\[2ex] \lambda_m=0,\quad \text{if } Q_{m\max}>Q_m(\Omega_1,\ldots,\Omega_M),\\ \lambda_m>0,\quad \text{if } Q_{m\max}=Q_m(\Omega_1,\ldots,\Omega_M),\end{array}\right.\\ \left\{\begin{array}{l}\dfrac{\partial^2}{\partial S_m^2}L(\Omega_1^*,\ldots,\Omega_m^*,\ldots,\Omega_M^*)<0,\\[2ex] \dfrac{\partial^2}{\partial V_m^2}L(\Omega_1^*,\ldots,\Omega_m^*,\ldots,\Omega_M^*)<0,\\[2ex] \dfrac{\partial^2}{\partial F_m^2}L(\Omega_1^*,\ldots,\Omega_m^*,\ldots,\Omega_M^*)<0,\\[2ex] \dfrac{\partial^2}{\partial A_m^2}L(\Omega_1^*,\ldots,\Omega_m^*,\ldots,\Omega_M^*)<0,\\[2ex] \dfrac{\partial^2}{\partial C_m^2}L(\Omega_1^*,\ldots,\Omega_m^*,\ldots,\Omega_M^*)<0,\\[2ex] \lambda_m=0,\quad \text{if } Q_{m\max}>Q_m(\Omega_1,\ldots,\Omega_M),\\ \lambda_m>0,\quad \text{if } Q_{m\max}=Q_m(\Omega_1,\ldots,\Omega_M).\end{array}\right.\end{array} \tag{19}$$

Therefore, all modes of travel can maximize their own interests, and the Nash equilibrium solution of the game is $\Omega_m^* = (\Omega_1^*,\ldots,\Omega_m^*,\ldots,\Omega_M^*)$.

However, when the mth travel mode is used for strategic adjustment, other travel modes will adopt corresponding strategies to ensure their own interests. When the travel mode k $(k \neq i)$ realizes the maximum benefit $\max\pi_k(\Omega_k^*/\Omega_1,\ldots,\Omega_m^*,\ldots,\Omega_{k-1},\Omega_{k+1},\ldots,\Omega_M)$ under the new market environment through the strategy adjustment, the maximum benefit $\max\pi_m(\Omega_m^*/\Omega_1,\ldots,\Omega_{m-1},\Omega_{m+1},\ldots,\Omega_M)$ of the travel mode m has not reached the expected maximum benefit under the new strategy of other travel modes. Therefore, a new round of strategic adjustment is bound to be made again [58]. Only when all participants cannot obtain higher benefits through the adjustment of the strategy, the game is dynamically balanced at this time, and the resulting policy set is a conditionally satisfied Nash equilibrium solution.

Therefore, the game order is as follows:

(1) Under current conditions, the strategy $\Omega_m^* = (\Omega_1^*,\ldots,\Omega_m^*,\ldots,\Omega_M^*)$ of maximizing one's own interests will be taken into consideration, regardless of whether the current tactical choices can maximize the interests of the other participants.

(2) Each participant makes new coping strategies based on the strategies adopted by other competitors and ensures that their own interests are always maximized $\max\pi_m(\Omega_m^{**}/\Omega_1^*,\ldots,\Omega_{m-1}^*,\Omega_{m+1}^*,\ldots,\Omega_M^*)$.

(3) If a strategy set $(\Omega_1^*,\ldots,\Omega_m^*,\ldots,\Omega_M^*)$ can satisfy Equation (20), the strategy $(\Omega_1^*,\ldots,\Omega_m^*,\ldots,\Omega_M^*)$ satisfying this inequality system is a Nash equilibrium solution of the game:

$$\begin{array}{l} \pi_1(\Omega_1^*/\Omega_2^*,\ldots,\Omega_m^*,\ldots,\Omega_M^*)\\ \quad > \pi_1(\Omega_1^*/\Omega_2^*,\ldots,\Omega_m^*,\ldots,\Omega_M^*),\\ \qquad\vdots\\ \pi_m(\Omega_m^*/\Omega_1^*,\ldots,\Omega_{m-1}^*,\Omega_{m+1}^*,\ldots,\Omega_M^*)\\ \quad > \pi_m(\Omega_m/\Omega_1^*,\ldots,\Omega_{m-1}^*,\Omega_{m+1}^*,\ldots,\Omega_M^*),\\ \qquad\vdots\\ \pi_M(\Omega_M^*/\Omega_2^*,\ldots,\Omega_m^*,\ldots,\Omega_{M-1}^*)\\ \quad > \pi_M(\Omega_M^*/\Omega_2^*,\ldots,\Omega_m^*,\ldots,\Omega_{M-1}^*). \end{array} \tag{20}$$

(4) In all equilibrium situations that satisfy the requirements, the equilibrium strategy set $(\Omega_1^{**},\ldots,\Omega_m^{**},\ldots,\Omega_M^{**})$, where the competitors take the best measures to maximize their own benefits, is the optimal solution of the model.

To determine the optimal solution, the concept of relative satisfaction $\eta_m(\eta \in [0,1])$ is introduced and calculated by the following equation [59]:

$$\eta_m = \frac{\pi_m(\Omega_i/\Omega_1,\ldots,\Omega_{m-1},\Omega_{m+1},\ldots,\Omega_M)}{\max\limits_{m=1,2,\ldots,M}\left[\pi_m(\Omega_i/\Omega_1,\ldots,\Omega_{m-1},\Omega_{m+1},\ldots,\Omega_M)\right]}. \tag{21}$$

If and only if the mth travel mode adopts the strategy $(\Omega_m^{**}/\Omega_1^*, \ldots, \Omega_{m-1}^*, \Omega_{m+1}^*, \ldots, \Omega_M^*)$, the maximum satisfaction $\max\eta_m = 1$ is obtained and the maximum benefit $\max\pi_m(\Omega_m^{**}/\Omega_1^*, \ldots, \Omega_{m-1}^*, \Omega_{m+1}^*, \ldots, \Omega_M^*)$ is obtained.

4.2. Solving Steps of Nash Equilibrium Solution

Step 1. Each game participant formulates the optimal strategy $\Omega_m^*(S_m, V_m, F_m, A_m, C_m)$ under the current conditions to calculate the current market share and income.

Step 2. Each participant calculates the income after $a-1$ times of game, then formulates the game strategy of the next game, and calculates the profit $\pi_{m/a}(\Omega_{m/a}^{**}/\Omega_{1/a-1}^*, \ldots, \Omega_{m-1/a-1}^*, \Omega_{m+1/a-1}^*, \ldots, \Omega_{M/k-1}^*)$ after a times game.

Step 3. The satisfaction η_m of each participant after the ath strategy adjustment is calculated, and whether the value of $\sum_{m=1}^{M}\eta_m$ satisfies the judgment condition $\sum_{m=1}^{M}((\pi_m(\Omega_m^{**}/\Omega_1^*,\ldots,\Omega_{m-1}^*,\Omega_{m+1}^*,\ldots,\Omega_M^*))/(\max_{m=1,2,\ldots,M}[\pi_m(\Omega_m/\Omega_1,\ldots,\Omega_{m-1},\Omega_{m+1},\ldots,\Omega_M)]))-M<\varepsilon$ is discussed. If being satisfied, skip to Step 4; otherwise, skip to Step 2.

Step 4. The optimal solution $\Omega_m^{**}/\Omega_1^*, \ldots, \Omega_{m-1}^*, \Omega_{m+1}^*, \ldots, \Omega_M^*$ is obtained, and the market share M_m and trip volume Q_m of various travel modes are calculated; then, the final calculation is finished.

5. Case Study: Zhengzhou Academy Street Historic Districts

5.1. Travel Mode Optimal Sharing Forecast. After several years of construction and development, the historic city road facilities have formed a relatively complete traffic network system, and there is little potential for the further development of infrastructure to mitigate traffic pressure due to the protection of landscape features. Therefore, it is necessary to change the existing modes of traffic development and find other alternative ways to solve urban traffic problems. The Academy Street is the most historic living residential district in Zhengzhou city. The boundaries of the Academy Street historical district are east to Chengdong Road, west to Shuncheng Street, north to Shangcheng Road, and south to Chengnan Road. Due to its location in the old city, the district has largely preserved its traditional historical features (Figure 2) [60–62]. Meanwhile, the current situation of land use in the districts is complicated, and there are many modern commercial facilities such as large commercial centers, general hospitals, and schools. Therefore, traffic flow and people flow in the inner districts are relatively large. Some streets within the districts, however, still retain historical features. The road section is a plate, and the road width is generally narrow. At the same time, motor vehicles and nonmotor vehicles are seriously mixed. Because the protection of historic districts is an important task, the construction and widening of the roads have been greatly restricted. The contradiction between lower travel capacity and higher travel needs results in a considerable proportion of bicycle and walking sharing.

To predict the internal travel structure of the historic district of Academy Street, the demand for each OD pair in the district should be obtained first, and then the travel mode share of each OD pair is calculated based on the prediction model so as to achieve the demand of various travel modes in the whole historical district. Currently, there are two common methods to obtain OD matrix, one is obtained by large-scale traffic survey, but the process of traffic investigation is time-consuming and laborious, and the later data processing workload is huge. In the late 1970s, scholars put forward a method to estimate the OD matrix by road traffic volume, that is, the second method to obtain the OD matrix: OD matrix backstepping method. The OD matrix backstepping program in software TransCAD considers the randomness of road section survey, and the matrix estimation function can be realized using any allocation method through multiple iterations between traffic assignment and matrix estimation. The program is mainly based on Nielsen's research results in 1993 and 1998: single path OD matrix estimation method (SPME) and multipath OD matrix estimation method (MPME) [63]. The advantage of this method is that based on the observed section flow in the current road network, the observed flow is regarded as a random variable and can be used in any traffic assignment method, such as the random user equilibrium assignment method and the user equilibrium assignment method. This method combines with modern traffic observation technology to reduce costs while improving efficiency [64]. Therefore, in this paper, the OD matrix backstepping procedure in software TransCAD is used to get the OD matrix.

Firstly, a road network zoning model within the scope of the study is established using the TransCAD software. On the basis of the area and the main street, the districts will be divided into six districts (1–6). The selected research scope in the study, however, is not entirely closed. Considering the impact of trip activities on research results, including that travelers in the block travel outside the block and travelers outside the block travel inside the block, three virtual residential areas (7–9) are delimited to the west of Shuncheng Street and north of Shangcheng Road, which can reduce the error effect of transregional travel on the result. The southern and eastern side of the study area is a fully preserved ancient city wall of the Ming Dynasty, and there is no possibility of transregional travel, so no virtual residential area is established. The whole area of analysis is 242 hectares, the North-South length is 1100 m, and the East-West length is 2200 m (Figure 3). Subsequently, the current OD matrix is obtained. The input required by the OD matrix estimation program includes the observed traffic volume in the road network, the seed (initial) OD matrix, and the input parameters required by the selected traffic assignment method. Firstly, the traffic volume of the main streets in the block during the morning peak (7:00–8:00) and evening peak (5:30–6:30) was investigated detailedly. Later, the modeling analysis of the road network in the research area was conducted using TransCAD software. And then, the survey data was loaded into the

Figure 2: Distribution of the traditional elements in Academy Street.

Figure 3: The division of the traffic areas of Academy Street.

TransCAD software. In the geographic files of TransCAD software, each traffic area has an associated point called centroid. The centroid of the traffic zone is the centroid point of the area, and also the trip virtual point of the district. The travel of the zone is approximately thought to occur at this point, which is similar to the physical center of mass, but not necessarily the geometric center of the traffic zone. In this case study, the centroid output function of TransCAD software is used to generate the centroid of the traffic area, and the connecting rods between centroids are made.

In this case study, the iteration number of the OD matrix estimation procedure is set to 20, and the convergence criteria are set to 0.000001. The road section information input in TransCAD software includes road grade, capacity, free flow speed, and measured traffic volume (peak period). The traffic assignment method based on stochastic user equilibrium is used to estimate the OD matrix, which is considered to be the traffic assignment method with the minimum mean error in OD backstepping [65–67]. The seed OD matrix is derived from the calculation of interval-valued impedance. By using the command of "Networks/Paths-Multiple Paths" in TransCAD software, the travel distances or travel times of several shortest paths between the centroid points of different traffic zones in the road network of Academy Street historic district can be calculated, which can be used as the travel impedance matrix between traffic zones, and then, the seed OD matrix can be calculated according to Equation (22), and the current OD matrix of each traffic zone is obtained by using the OD backstepping method, as shown in Table 1:

$$t_{ij} = 1 - \frac{f_{ij}}{\sum_i \sum_j f_{ij}}, \tag{22}$$

where t_{ij} is the proportion of the travel volume between traffic zone i and traffic zone j in the seed OD matrix, f_{ij} is the impedance value in the travel impedance matrix between traffic zone i and traffic zone j, and the travel time is selected as the impedance value in this paper.

It is noteworthy that the object of the game model presented is the traveler, travel mode, and travel behavior in the historic districts. By analyzing the environmental characteristics of many well-known historic districts, the area of historic district is generally small, and the distance between OD pairs is generally short, which is generally no more than 3 km. Furthermore, according to the results of RP survey on travelers, most of the travelers in historic districts are traveling in a single mode. Therefore, the multimode trips of travelers need not be considered in the model presented. The model in this paper is not applicable to large urban areas with multimode trips or long OD pairs, as well as to regions where travelers generally employ multimode trips.

Q_{Tij} is the volume of travel in each OD pair. The average time value $\overline{v} = 10.68$ dollar/h, $\overline{v} \in [10, 20]$. The random taste coefficient of the model $\theta = -1$. Average travel speed of different travel modes at peak hours: $\overline{V}_{\text{walk}} = 5.5$ km/h, $\overline{V}_{\text{walk}} \in [4, 10]$, $\overline{V}_{\text{bicycle}} = 15.5$ km/h, $\overline{V}_{\text{bicycle}} \in [10, 30]$, $\overline{V}_{\text{car}} = 30$ km/h, $\overline{V}_{\text{car}} \in [20, 50]$, $\overline{V}_{\text{bus}} = 25$ km/h, and $\overline{V}_{\text{bus}} \in [15, 40]$. In this example, $Q_T = 50550$ (person/h), according to the constraints, the maximum traffic volume calculated for each mode of traffic is $Q_{\text{car}} = 2880$ (person/h), $Q_{\text{bus}} = 10400$ (person/h), $Q_{\text{Pedestrian}} = 14500$ (person/h), and $Q_{\text{bicycle}} = 26850$ (person/h), and this constraint is set up in the study as programme 1. Through the traffic survey data of the districts, the parameters of the nonaggregated logit model are calibrated, and the values of the parameters are shown in Table 2. According to the steps, the optimal sharing rate and travel volume of each OD traffic between each pair are calculated. Taking a bicycle as an example, the calculation results are shown in Table 3, and the share amount of the other travel modes is shown in Figure 4.

The results of the game show that the soft modes have become the main travel mode in the traffic system of the Academy Street historical districts. The prediction results are summarized as follows:

(1) Except for the error factors, the shares of walking and bicycle increase by 5.99% and 9.09%, respectively. Meanwhile, the shares of car and bus decrease by 61.15% and 4.67%, respectively. Soft modes become the most important transportation mode for districts, with a market share of 76.29%.

(2) The share of bicycle travel has increased significantly, and its market share (53.41%) also occupies an absolute advantage, which shows that the traveler prefers to travel by a bicycle after restricting the traffic volume of motor vehicles.

(3) The share of walking travel increases in a small range, and the total travel volume are generally stable, which is related to poor travel comfort and slow travel speed.

(4) From the comparison of data, the share of walking is about 2% higher when the distance is less than 1.5 kilometers, compared with that when the distance is more than 1.5 kilometers. The share of bicycle within 2 to 4 kilometers is also about 2% higher than other travel distances.

5.2. Comparison and Analysis of Model Results. The above noncooperative game models presented in the study are calculated by digital simulation. Through the change of the constraints, the change of Nash equilibrium solution is observed, which provides the basis for the formulation of the competition strategy in the noncooperative competition of the historical districts. Assuming that the travel volume Q_{Ti} between the OD pairs is constant, the average time value of the travelers, the average speed of each travel mode, the random perceptual coefficient of the model, and the values of the parameters α_m, β_m, γ_m, μ_m, and ω_m do not change. If the restrictions on motor vehicles caused by environmental pollution are not taken into account, the maximum traffic volume limits for cars and buses shall be changed to $Q_{\text{car}} = 7000$ (person/h). When $Q_{\text{bus}} = 12000$ (person/h), and this constraint is set up in the study as programme 2. Then, the optimal share and travel volume of transportation modes between each OD pair are recalculated. The change of the OD value for each travel mode is shown in Figure 5.

The results of the two game models and the current traffic results are compared and analyzed. The results are as follows:

(1) By comparing the results of the two game models, it can be seen that the market share allocation of the four modes is related to their traffic volume constraints, and the ratio of traffic volume constraints of each mode is equivalent to its market share.

(2) By comparing the traffic structure of programme 1 with that of programme 2, the share of motor vehicles will be greatly increased with the increase of traffic volume constraint in the game model, indicating that the automobile is still the favorite transportation mode in historic street for the travelers. If the volume of car traffic is not restricted, the market share of cars will continue to rise. By comparing programme 1 with the current traffic structure, it can be seen that only by strictly restricting the traffic volume of cars can the proportion of cars be effectively reduced. By comparing programme 2 with

Table 1: The current travel OD of the Academy Street (person/h).

O	D 1	2	3	4	5	6	7	8	9
1	0	731.37	810.32	868.21	756.56	888.74	769.63	737.76	721.64
2	753.21	0	827.46	712.93	695.62	735.73	629.65	754.23	721.76
3	628.13	876.89	0	834.41	642.23	787.79	589.76	715.37	697.85
4	826.35	782.37	678.92	0	743.47	729.67	809.83	621.54	662.57
5	687.89	746.84	698.57	768.79	0	808.93	649.72	607.54	713.47
6	732.36	697.68	768.75	679.57	763.12	0	612.88	656.17	703.25
7	659.31	703.87	632.43	645.73	587.76	546.73	0	673.57	587.93
8	703.53	724.42	646.81	691.24	642.37	521.21	687.92	0	746.31
9	667.11	653.28	752.64	587.58	631.53	592.47	546.87	679.58	0

Table 2: Logit model parameter calibration values for travel modes in Academy Street historic districts.

Travel mode	α_m	β_m	γ_m	μ_m	ω_m
Walking	0.09	0.36	0.09	0.10	0.36
Bicycle	0.16	0.23	0.24	0.12	0.25
Car	0.18	0.18	0.23	0.16	0.25
Bus	0.19	0.17	0.23	0.18	0.23

Table 3: The optimal share rate of bus travel in Academy Street historical districts.

$M_{m_{ij}}^{bus}$	1	2	3	4	5	6	7	8	9
1	0	0.2451	0.2618	0.2355	0.2348	0.2439	0.2127	0.2105	0.2260
2	0.2379	0	0.2350	0.2156	0.2055	0.2319	0.2436	0.2282	0.2241
3	0.2468	0.2473	0	0.2529	0.2412	0.2127	0.2642	0.2341	0.2085
4	0.2366	0.2139	0.2553	0	0.2114	0.2358	0.2222	0.2164	0.2614
5	0.2341	0.2139	0.2373	0.2080	0	0.2126	0.2243	0.2258	0.2286
6	0.2422	0.2322	0.2156	0.2384	0.2101	0	0.2615	0.2667	0.2531
7	0.2116	0.2485	0.2674	0.2164	0.2274	0.2555	0	0.2520	0.2680
8	0.2196	0.2238	0.2391	0.2209	0.2344	0.2686	0.2554	0	0.2445
9	0.2417	0.2213	0.2142	0.2702	0.2345	0.2409	0.2715	0.2353	0

the current traffic structure, it can be seen that if the number of cars is not constrained, the proportion of cars will continue to increase.

(3) By comparing the results of the two game models, after increasing the restriction of vehicle traffic volume, the bicycle trip share is obviously reduced, while the bus trip share is relatively stable. It proves that the most preferred mode of transportation for travelers in historic districts is bicycle travel after giving up using cars. It also shows that the competition between car travel and bicycle travel is the most intense.

(4) By comparing programmes 1 and 2 with the current traffic structure, the sharing of walking trip and bus trip is relatively stable, while the other two modes of transportation have less influence on their share rates. Meanwhile, the total amount of walking trip and bus trip is stable, indicating that the traveling groups of the two modes are relatively stable.

(5) When the urban traffic demand OD is constant, the operation state of the road network will be significantly different under different traffic modes. As detailed in Table 4, for the two different traffic structures of programme 1 and programme 2 solved through the game model, as well as the current traffic structure, the simulation results of their respective road network operation are obtained. The service class classification is according to Highway Capacity Manual 2000 (USA), and the service level of the road is judged according to the average travel speed. When the service level is A, it indicates that traffic flow is free flow, and the control of the vehicle is unhindered, basically without delay. When the service level is B, it indicates that the traffic flow is stable, the mobility of traffic flow is limited slightly, and the delay is not significant. When the service level is C, it indicates that the traffic flow can reach a stable operation condition, but the free driving of the vehicle is greatly limited. It is generally believed that the service level of urban roads above level C can satisfy the stable operation condition of motor vehicles, and the traffic condition of the road network can be considered as good. The traffic structure restricted by motor vehicle traffic volume can greatly improve the service level of the road network. If the traffic volume of motor vehicles is strictly restricted, the service level of road sections and intersections in historic urban areas can reach above the level C,

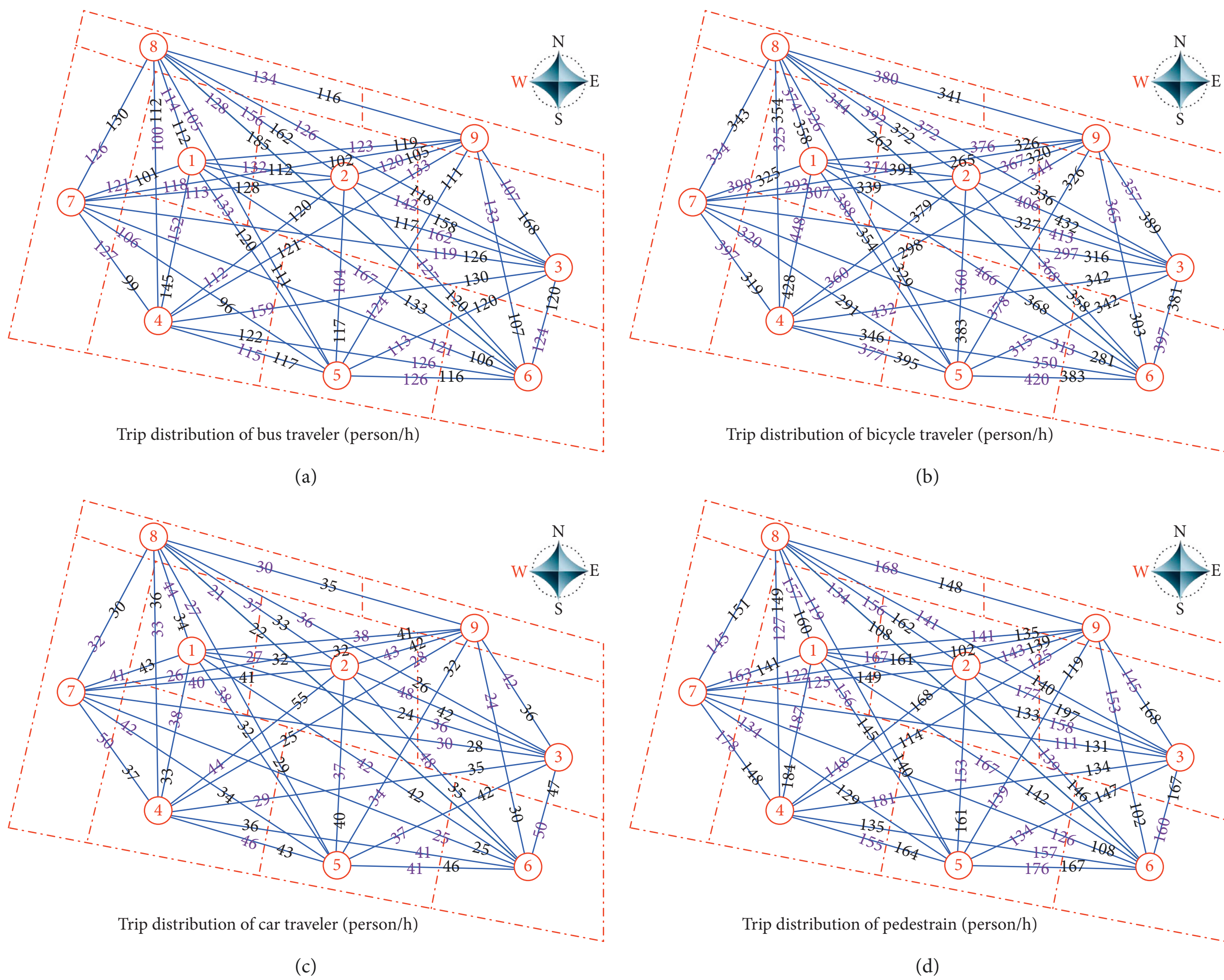

Figure 4: Trip distribution of each travel mode.

effectively improving the operation of historic urban areas.

(6) The total amount of traffic pollutants emitted by different structural systems is different from the total energy consumed, and there are huge differences in the impact on the environment. After investigation, the market share of the new energy bus in Zhengzhou City accounts for 83%. Therefore, 17% of the bus traffic volume is used to calculate its environmental indicators. For the two different traffic structures of programme 1 and programme 2 solved through the game model, as well as the current traffic structure, the respective environmental simulation results are calculated as shown in Table 5.

By comparing the two traffic structures in this case, for the same scale of road network, different traffic modes correspond to different levels of road network service and different environmental indicators. The traffic structure generated by strict traffic volume constraint is less than second type of traffic structure in terms of pollutant emission, energy consumption, and space occupied area. As long as the traffic volume of motor vehicles is constrained, the road traffic operation and ecological environment can be effectively improved.

According to the above analysis, two different governance concepts are embodied in programmes 1 and 2. For programme 1, taking the ecological protection and sustainable development of historical blocks as the core, the traffic volume of cars must be strictly restricted to meet the environmental requirements of ecological protection so that the travel mode in the block gradually becomes the absolute subject of soft modes. The concept of traffic management in Zhengzhou historic districts at this stage is presented in programme 2; that is, the car traffic should be limited by a small margin, and, for example, the policy of limiting working days for motor vehicles is now being implemented. According to the calculation results of programme 2, the road operating environment and ecological environment can be effectively improved even if the traffic volume of motor vehicles is limited slightly; however, there is still a big gap from the standard of historical block protection conditions. For historical blocks in developing cities, because of land use and other reasons, there are still lots of residential areas in

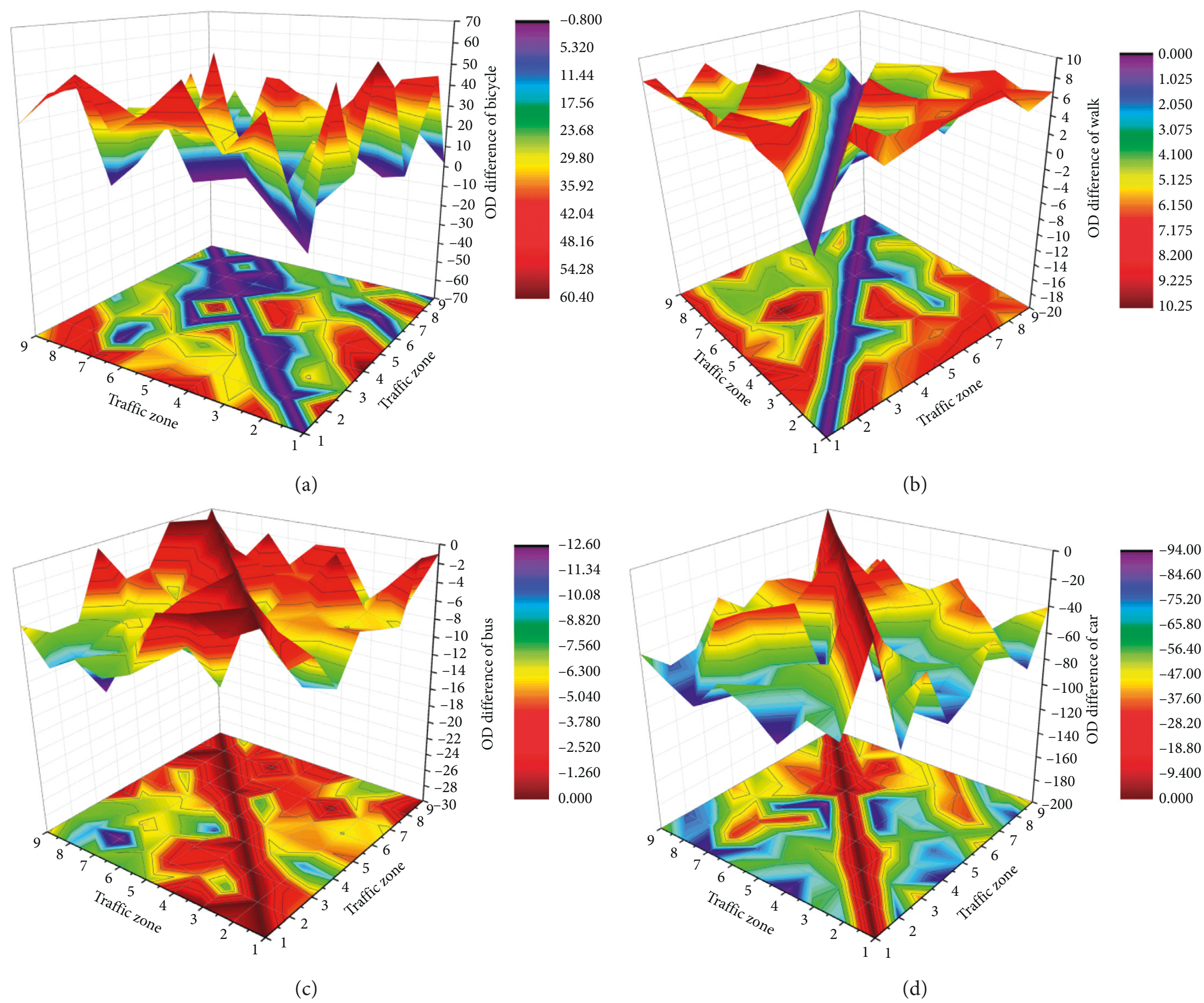

Figure 5: The OD value difference of each travel mode.

Table 4: Operational indicators of traffic flow under the two travel modes.

	Programme 1			Programme 2			Current traffic structure		
Service level classification	A	B	C	A	B	C	A	B	C
Road section (length) (%)	82.41	13.15	4.44	21.15	20.98	15.37	18.78	19.62	14.33
Intersection (number) (%)	78.53	12.76	8.71	22.51	21.42	14.69	19.24	19.73	13.96

Table 5: Environmental indicators under the two travel modes.

	CO emission (g)	NO*x* emission (g)	HC emission (g)	Energy consumption (MJ)	Static occupied space area (m^2)
Programme 1	308527	20455	68058	34969	120522
Programme 2	789311	51359	169635	75513	211272
Current traffic structure	815008	56574	187441	80635	221483

historical blocks. In addition, due to the poor infrastructure at the present stage, the choice of transportation modes is relatively small, and one-size-fits-all restrictions on car travel are still inappropriate. Therefore, in the process of implementing the traffic structure optimization of historic blocks, the two different governance concepts should be weighed carefully. According to the experience of international metropolitan development, each region has its own characteristics in the process of optimizing the traffic structure development. The formulation of traffic policy should be tailored to local conditions. Here are some suggestions that can help historic blocks improve their transport structures.

(1) Optimization and perfection of the street and lane system for historical blocks: the protection of road and lane system in historical street is an important part of protecting the historical environment, which can maintain the historical appearance of the block, including the maintenance of the nonmotorized traffic environment of the road and alley system through the proper renovation and renewal. It is necessary to protect the texture of streets and lanes and to achieve corresponding traffic and functionality. At the same time, we should weaken the vehicle system and reduce the attractiveness of car trips. The urban planners suggest that the blocks should be set up as pedestrian areas without motor traffic. However, cities should also meet the actual needs of modern life, especially for large-scale historical and cultural cities. It is not realistic to completely turn historic blocks into pedestrian areas, and it will also bring many inconveniences. Therefore, the road system (street system) of historic blocks should consider the mode of "the demand for motorized traffic is moderately satisfied on the basis of maintaining the historic nonmotorized traffic mode." For example, considering the Radburn idea road traffic system, the core protected area is set up, and traffic streets are set around the core reserve.

(2) Scientific analysis and organization of traffic links between historic districts and outlying urban areas: according to the guiding ideology of "guidance," the "guidance mode" is combined with the moderate "traffic control." To coordinate the development of motorized traffic and the protection of historical and cultural environment, firstly, historic blocks should be designated as nonmotorized traffic areas in terms of planning layout. According to the scale and current situation of historic blocks, scientific arrangement and organization of motorized traffic that must enter the blocks should be carried out. To protect the traffic environment of the block from excessive motor traffic interference, the good connection between the block and the surrounding urban area should be also considered. It not only maintains the good service of motor traffic to the block but also relieves the traffic pressure of the peripheral urban area and forms a good road network and traffic environment. Specific measures can be taken. For smaller blocks, traffic of the historic district can be restricted and controlled by traffic organization, and pedestrian areas can be set up in the blocks. In order to guide and implement the protection of the traffic environment of the block, a protective trunk road is planned and constructed on the periphery of the block. For example, in the 1980s, Xi'an, China, in order to protect the environment of the Ming Dynasty city wall completely, the ancient city wall park began to be built, protecting the historical environment of the ancient city walls and moats in Ming Dynasty. At the same time, the road was built outside the city wall park, forming the first traffic protection ring of the ancient city, which played a role in separating and connecting the traffic environment inside the ancient city and the modern traffic environment outside the ancient city.

(3) Scientific implementation of traffic management measures: scientific TDM (traffic demand management) should be implemented to reduce the disorderly entry of vehicles into historical blocks. Accordingly, a tranquil and convenient transportation system supplemented by soft modes and low-carbon public transport can be established gradually. Specific measures can be taken: according to the tail number of the car license plate, a single day limit measure is adopted for cars. For the peak hours of working days or the peak tourist periods of historical blocks on festivals and holidays, traffic control signs and facilities can be set up at the main intersections entering the blocks, the policy of prohibiting the entry of transit traffic or adopting congestion charges can be implemented, and the entry of freight vehicles or other vehicles can be restricted. For the parking management measures, on the one hand, the supply of parking space in the block can be controlled, and parking facilities at the junction of urban arteries and traffic streets around the block should be set up. On the other hand, parking fees can be raised appropriately, and the number of cars entering the block can be controlled and gradually reduced. For example, congestion charges in central London and low emission zones were set up in 2008. Additionally, a market-oriented high parking fee policy was adopted to reduce the upper limit of the number of parking spaces allocated for construction, and many restrictions on the use of cars were employed.

(4) Encouraging the implementation of public transport optimization strategy: on the one hand, the convenience of bus trip can be improved by increasing the density of bus stops in the block. If the demand of long-term express bus is to be met, bus lanes should be set up as far as possible. On the other hand, the service level of public transport should be improved, such as the adoption of new energy vehicles and the placement of intelligent bus service settings. It is suggested to enrich the public transport systems as necessary, such as adding subway, light rail, and public bicycle. For instance, Stockholm's block bus system is rich in traffic modes and offers a wide range of options for travelers, including trams, subways, buses, and public bicycles. Bus stations are evenly distributed, and the distance between stations is generally between 300 and 500 meters. Bus lanes are set up to facilitate travelers. Meanwhile, the level of public transport services has gradually improved with automatic takeoff and landing doors, intelligent arrival reminders, and other functions. Travelers would feel comfortable when they ride with interest

in bus riding being greatly improved. For example, since 2009, Singapore has improved the quality of bus services by shortening the intervals, increasing stations and optimizing routes. Under a series of combined measures, the proportion of public transport trips has risen sharply.

6. Conclusion

Taking Zhengzhou Academy Street district as an example, a dynamic game model is established in the study, which presents the optimal sharing rate and optimal traffic structure of the various transportation modes in the blocks.

(1) The dynamic game model is suitable for travel in historical blocks of developing cities. Because of most of the travelers in historic districts are traveling in a single mode, the multimode trips of travelers are need not be considered in the model presented. The game model in this paper is not applicable to large urban areas with multimode trips or long OD pairs, as well as to regions where travelers generally employ multimode trips.

(2) The dynamic game model of generalized cost is established to simulate the competitive relationship among different travel modes in historical districts. The travel expenses of each travel mode, which quantified by the dynamic game model of generalized fees, overcome the shortcomings of the inability to quantify the costs of walking and bicycle travel in the traditional prediction model and can more fully reflect the competition relationship between soft modes and motor vehicle traffic. Through the comparison and analysis of two different traffic structures obtained by changing the constraints in the game model, the change in the share of each travel mode and the sharing rate of each mode of travel conform to the market laws, which proves the correctness of the model. The simulation results of the two traffic structures can also reflect the traveler's travel preferences in the historical district.

(3) To effectively improve the traffic system and ecological environment of historical blocks in developing cities, it is necessary to formulate traffic policies scientifically, implement them prudently and comprehensively, and adjust measures to local conditions. To improve the traffic problems of historic blocks, we should mainly protect the environment of the blocks, adopt the guiding measures of "guidance," and combine "guidance" with "traffic control" to optimize and adjust appropriately. By encouraging low-carbon and convenient transportation, the historic blocks will gradually be built into a quiet and convenient traffic system with soft modes as the main and low-carbon public transport as the supplement, which is guided by scientific and strict traffic management measures. We should deal with the relationship between the development of urban motorized traffic and the protection of historic districts so as to achieve a win-win situation between the protection of historic and cultural environment and modern traffic services. Through employing these measures, we can coordinate the relationship between the development of urban motorized traffic and the protection of historic districts so as to achieve a win-win situation between the protection of historic and cultural environment and modern traffic services.

Data Availability

The traffic data listed in this paper are measured and obtained from the investigation in the Zhengzhou Academy Street area, including current situation of road operation, traveler's characteristic data, and travel characteristic data. The OD matrix data listed in this paper are obtained from the software TransCAD. The calculated data listed in this paper are obtained from the software MATLAB, including the optimal share rate of each travel mode and data of trip distribution.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this article.

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References

[1] F. Da Porto, M. Munari, and A. Prota, "Analysis and repair of clustered buildings: case study of a block in the historic city centre of L'Aquila (Central Italy)," *Construction and Building Materials*, vol. 38, pp. 1221–1237, 2013.

[2] H. M. Garcia, V. M. de la Calle, and Y. Claudia, "Cultural heritage and urban tourism: historic city centres under pressure," *Sustainability*, vol. 9, no. 8, p. 1346, 2017.

[3] L. Y. Wu, "Points on the regulatory detailed planning about Beijing old town," *City Planning Review*, vol. 22, no. 2, pp. 6–9, 1998.

[4] G. Evans, "Living in a world heritage city: stakeholders in the dialectic of the universal and particular," *International Journal of Heritage Studies*, vol. 8, no. 2, pp. 117–135, 2002.

[5] A. Downs, "Smart growth: why we discuss it than we do it," *Journal of the American Planning Association*, vol. 71, no. 4, pp. 367–378, 2005.

[6] X. Li, X. Qu, C. Qi, and Z. Shao, "A unified analytical method calculating brittle rocks deformation induced by crack growth," *International Journal of Rock Mechanics and Mining Sciences*, vol. 113, pp. 134–141, 2019.

[7] Q. P. Wang, H. Sun, and Q. Zhang, "A bayesian network model on the public bicycle choice behavior of residents: a case study of Xi'an," *Mathematical Problems in Engineering*, vol. 2017, Article ID 3023956, 13 pages, 2017.

[8] D. Milakis, T. Vlastos, and N. Barbopoulos, "Relationships between urban form and travel behavior in Athens, Greece: a comparison with western European and north American

results," *European Journal of Transport and Infrastructure Research*, vol. 8, no. 3, pp. 201–215, 2008.

[9] Z. J. Zhou, C. N. Ren, G. J. Xu, H. C. Zhan, and T. Liu, "Dynamic failure mode and dynamic response of high slope using shaking table test," *Shock and Vibration*, vol. 2019, Article ID 4802740, 15 pages, 2019.

[10] Z. Zhang, H. Zhang, Y. Tan, and H. Yang, "Natural wind utilization in the vertical shaft of a super-long highway tunnel and its energy saving effect," *Building and Environment*, vol. 145, pp. 140–152, 2018.

[11] L. Rotaris and R. Danielis, "The impact of transportation demand management policies on commuting to college facilities: a case study at the University of Trieste," *Transportation Research Part A*, vol. 67, pp. 127–140, 2014.

[12] R. Ewing, S. Hamidi, F. Gallivan, A. C. Nelson, and J. B. Grace, "Combined effects of compact development, transportation investments, and road user pricing on vehicle miles traveled in urbanized areas," *Transportation Research Record*, vol. 2397, no. 1, pp. 117–124, 2013.

[13] S. K. Kakaraparthi and K. M. Kockelman, "Application of urbanSim to the Austin, Texas, region: integrated-model forecasts for the year 2030," *Journal of Urban Planning and Development*, vol. 137, no. 3, pp. 238–247, 2010.

[14] T. Yigitcanlar and F. Dur, "Developing a sustainability assessment model: the sustainable infrastructure, land-use, environment and transport model," *Sustainability*, vol. 2, no. 1, pp. 321–340, 2010.

[15] A. de Nazelle, S. Fruin, D. Westerdahl et al., "A travel mode comparison of commuters' exposures to air pollutants in Barcelona," *Atmospheric Environment*, vol. 59, pp. 151–159, 2012.

[16] H. William, K. Lam, C. L. Zhi, and J. H. Hai, "The impact of stop-making and travel time reliability on commute mode," *Transportation Research Part B*, vol. 40, no. 9, pp. 709–730, 2006.

[17] J. Qiu, T. Yang, X. Wang, and G. Zhang, "Review of the flame retardancy on highway tunnel asphalt pavement," *Construction and Building Materials*, vol. 195, pp. 468–482, 2019.

[18] L. A. Jeffrey and M. Cetin, "A direct redistribution model of congestion pricing," *Transportation Research Part B*, vol. 35, no. 3, pp. 447–460, 2001.

[19] J. Lai, J. Qiu, H. Fan, Q. Zhang, J. Wang, and J. Chen, "Fiber Bragg grating sensors-based in-situ monitoring and safety assessment of loess tunnel," *Journal of Sensors*, vol. 2016, Article ID 8658290, 10 pages, 2016.

[20] Y. Y. Wang and H. P. Lu, "Integrated model of urban land-use and modal split basedon sustainable development," *Journal of Tsinghua University (Science and Technology)*, vol. 44, no. 9, pp. 23–36, 2004.

[21] J. Lu and W. Wang, "The study of urban transportation system sustained development evaluation method," *China Civil Engineering Journal*, vol. 3, pp. 99–104, 2004.

[22] C. G. Prato, H. Katrin, and N. O. Anker, "Latent lifestyle and mode choice decisions when travelling short distances," *Transportation*, vol. 44, no. 6, pp. 1343–1363, 2017.

[23] T. Tabuchi, "Bottleneck congestion and modal split," *Journal of Urban Economics*, vol. 34, no. 3, pp. 414–431, 1993.

[24] K. Mark and K. Vladimir, "Optimization of an urban transport system on the condition of different goals of municipal authorities, operators and passengers," *Transport*, vol. 31, no. 1, pp. 63–69, 2016.

[25] L. Erikson and A. M. Nordlund, "GarvillJ. Expected car use reduction in response to structural travel demand management measures," *Transportation Research Part F*, vol. 13, no. 5, pp. 329–342, 2010.

[26] M. Habibian and M. Kermanshah, "Coping with congestion: understanding the role of simultaneous transportation demand management policies on commuters," *Transport Policy*, vol. 30, pp. 229–237, 2013.

[27] H. Y. Wang, "Research on methods for value of time determination for passenger behavior," *Journal of Highway and Transportation Research and Development*, vol. 21, no. 8, pp. 134–137, 2004.

[28] L. R. Tara and Z. Josias, "Sustainable transportation-alternative perspectives and enduring challenges," *International Journal of Urban Sciences*, vol. 20, no. 4, pp. 318–333, 2016.

[29] B. M. Teresa, T. Vincenzo, and N. Peter, "An operational information systems architecture for assessing sustainable transportation planning: principles and design," *Evaluation and Program Planning*, vol. 32, no. 4, pp. 381–389, 2009.

[30] X. Nie, X. Wei, X. Li, and C. Lu, "Heat treatment and ventilation optimization in a deep mine," *Advances in Civil Engineering*, vol. 2018, Article ID 1529490, 12 pages, 2018.

[31] B. Yann, G. Asma, and J. Zied, "Sustainable transportation and order quantity: insights from multiobjective optimization," *Flexible Services and Manufacturing Journal*, vol. 28, no. 3, pp. 367–396, 2016.

[32] A. Awasthi, S. S. Chauhan, and H. Omrani, "Using AHP and dempster–Shafer theory for evaluating sustainable transport solutions," *Environmental Modelling and Software*, vol. 26, no. 6, pp. 787–796, 2011.

[33] A. Anjali, S. Satyaveer, and H. O. Chauhan, "Application of fuzzy TOPSIS in evaluating sustainable transportation systems," *Expert Systems with Applications*, vol. 38, no. 10, pp. 12270–12280, 2011.

[34] R. Sonu, P. Parthiban, and R. Dhanalakshmi, "Sustainable transportation systems performance evaluation using fuzzy logic," *Ecological Indicators*, vol. 71, pp. 503–513, 2016.

[35] S. Samberg, A. Bassok, and S. Holman, "Method for evaluation of sustainable transportation toward a comprehensive approach," *Transportation Research Record*, vol. 2242, no. 1, pp. 314–317, 2012.

[36] D. Yoshino, A. Fujiwara, and J. Y. Zhang, "Environmental efficiency model based on data envelopment analysis and its application to environmentally sustainable transport policies," *Transportation Research Record*, vol. 2163, no. 1, pp. 112–123, 2010.

[37] K. Konstantinos, M. Vincent, N. Karin et al., "Quality management in mobility management: a scheme for supporting sustainable transportation in cities," *International Journal of Sustainable Transportation*, vol. 6, no. 4, pp. 238–256, 2012.

[38] S. Dhar and P. R. Shukla, "Low carbon scenarios for transport in India: co-benefits analysis," *Energy Policy*, vol. 81, pp. 186–198, 2015.

[39] S. Y. Zhou, "Optimization of urban transit structure based on sustained development," *Journal of Transportation Systems Engineering and Information Technology*, vol. 2, pp. 106–110, 2006.

[40] T. F. Fwa and B. W. Ang, "Energy savings due to land transportation management in Singapore," *Journal of Advanced Transportation*, vol. 30, no. 2, pp. 71–84, 1996.

[41] U. Mörtberg, J. Haas, A. Zetterberg, J. P. Franklin, and D. Jonsson, "Urban ecosystems and sustainable urban development—analysing and assessing interacting systems in the Stockholm region," *Urban Ecosystems*, vol. 16, no. 4, pp. 763–782, 2013.

[42] A. H. David, "Congestion charging: lessons from the first 6 months of the London experience and its scalability to Sydney," *Road and Transport Research*, vol. 12, no. 4, pp. 239–246, 2003.

[43] X. Luo, L. Niu, and S. Zhang, "An algorithm for traffic flow prediction based on improved SARIMA and GA," *KSCE Journal of Civil Engineering*, vol. 22, no. 10, pp. 4107–4115, 2018.

[44] Y. Li, S. Xu, H. Liu et al., "Displacement and stress characteristics of tunnel foundation in collapsible loess ground reinforced by jet grouting columns," *Advances in Civil Engineering*, vol. 2018, Article ID 2352174, 16 pages, 2018.

[45] Transport for London, *Travel in London Report 9*, Transport for London, London, UK, 2015.

[46] S. Cairns, L. Sloman, C. Newson, J. Anable, A. Kirkbride, and P. Goodwin, "Smarter choices: assessing the potential to achieve traffic reduction using 'soft measures'," *Transport Review*, vol. 28, no. 5, pp. 593–618, 2008.

[47] W. Brog, E. Erl, I. Ker, J. Ryle, and R. Wall, "Evaluation of voluntary travel behaviour change:Experiences from three Continents," *Transport Policy*, vol. 16, pp. 281–292, 2009.

[48] S. He, L. Su, H. Fan, and R. Ren, "Methane explosion accidents of tunnels in SW China," *Geomatics, Natural Hazards and Risk*, 2018.

[49] O. F. Shyr and Y.-P. Kuo, "Applying TOPSIS and cooperative game theory in airline merging and coalition decisions," *Journal of Marine Science and Technology*, vol. 16, no. 1, pp. 8–18, 2008.

[50] C. Chu, "A paired combinatorial logit model for travel demand analysis," in *Proceedings of the Fifth World Conference on Transportation Research*, vol. 4, Ventura, CA, USA, 1989.

[51] J. L. Bowman and M. Ben-Akiva, "Activity-based disaggregate travel demand model system with activity schedules," *Transportation Research Part A*, vol. 35, pp. 1–28, 2000.

[52] D. MeFadden, *Econometric Analysis of Qualitative Response Models, Working Paper, Department of Economics*, Elsevier, New York, NY, USA, 1982.

[53] C. Folke, A. Jansson, and J. Lansson, "Ecosystem appropriation by cities," *Ecology Economics*, vol. 26, pp. 163–168, 1997.

[54] A. Carlsson-Kanyma and A. Linden, "Travel patterns andenvironmental effects now and in the future: implications of differences in energy consumption among socio-economics groups," *Ecological Economics*, vol. 30, pp. 405–417, 1999.

[55] R. Jiang and Q. S. Wu, "Kinematicwave properties of anisotropic dynamics model for traffic flow," *Transportation Research Part B Methodological*, vol. 23, no. 4, pp. 409–414, 2002.

[56] J. F. Nash, "Non-cooperative games," *Annals of Mathematics*, vol. 54, no. 2, pp. 286–295, 1951.

[57] X. Zhou and J. H. Ji, "Evolutionary game analysis of port competition cooperation strategy," *Navigation of China*, vol. 31, no. 3, pp. 293–297, 2008.

[58] Y. Schipper, P. Nijkamp, and P. Rietveld, "Deregulation and welfare in airline markets: an analysis of frequency equilibria," *European Journal of Operational Research*, vol. 178, no. 1, pp. 194–206, 2007.

[59] Y. Zhu, "Typology method in historic block protection," *Urban Planning Forum*, vol. 6, pp. 57–60, 2002.

[60] J. L. Qiu, X. L. Wang, S. Y. He, H. Q. Liu, J. X. Lai, and L. X. Wang, "The catastrophic landside in Maoxian county, sichuan," *Natural Hazards*, vol. 89, no. 3, pp. 1485–1493, 2017.

[61] J. Lai, X. Wang, J. Qiu, J. Chen, Z. Hu, and H. Wang, "Extreme deformation characteristics and countermeasures for a tunnel in difficult grounds in southern Shaanxi, China," *Environmental Earth Sciences*, vol. 77, no. 706, pp. 1–14, 2018.

[62] J. Lai, K. Wang, J. Qiu, F. Niu, J. Wang, and J. Chen, "Vibration response characteristics of the cross tunnel structure," *Shock and Vibration*, vol. 2016, Article ID 9524206, 16 pages, 2016.

[63] L. M. Martinez, J. M. Viegas, and E. A. Silva, "A traffic analysis zone definition: a new methodology and algorithm," *Transportation*, vol. 36, no. 5, pp. 581–599, 2009.

[64] X. Li and H. P. Lu, "OD matrix analysis of motor vehicle based on video identification data," *Highway Engineering*, vol. 6, pp. 170–188, 2014.

[65] X. L. Wei, H. F. Li, Y. B. Geng, and J. X. Lin, "Contrast research on OD matrix estimation result withTransCAD software," *Highway*, vol. 6, pp. 122–128, 2007.

[66] J. Lai, S. He, J. Qiu et al., "Characteristics of seismic disasters and aseismic measures of tunnels in wenchuan earthquake," *Environmental Earth Sciences*, vol. 76, no. 94, pp. 1–19, 2017.

[67] X. Luo, D. Li, S. Zhang et al., "Traffic flow prediction in holidays based on DFT and SVR," *Journal of Sensors*, vol. 2019, Article ID 6461450, 9 pages, 2019.