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Article

The Impact of Transportation Resource Allocation Efficiency on Residents' Travel Utility

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Abstract: The introduction of the "dual carbon" goals and the national strategy of building a strong transportation system has placed higher demands on the efficient allocation of transportation resources and the development of green mobility systems in China. The relationship between transportation resource allocation and residents' travel utility has become the focus of social attention. Based on the panel data of 162 cities in China from 2003 to 2022, this paper calculates the efficiency of transportation resource allocation and the utility of residents' travel through the super-efficiency SBM model and the entropy method, and empirically tests the impact effect, impact path and threshold effect between the two, taking into account the moderating role of government intervention. The study finds that the efficiency of transportation resource allocation can significantly improve the travel utility of residents, and there is a significant double threshold effect. The mechanism test proves that the efficiency of transportation resource allocation can improve residents' travel utility by improving the level of urbanization, mitigating environmental pollution and reducing the number of traffic accident deaths. Government intervention can reduce the promotion effect of transportation resource allocation efficiency on residents' travel utility. In addition, when the efficiency of transportation resource allocation is in the second threshold range, the improvement effect on residents' travel utility is the best. If the efficiency value is lower than the first threshold value, it will have a negative effect on residents' travel utility. Therefore, moderate government intervention and rational allocation of transportation resources are particularly important for improving residents' travel utility.

Keywords: transportation resource allocation; travel utility; government intervention; urbanization level

1. Introduction

At present, China's economic growth has also transformed into a two-wheel drive process of industrialization and urbanization. As the main node of the global economic network, cities are deeply involved in international competition and cooperation, attracting domestic and foreign population, capital, technology and other factors to accelerate agglomeration. Based on the national economic operation report released by the National Bureau of Statistics in January 2025, it is found that the urbanization level of China 's permanent population at the end of 2024 is 67%, which is 26.47 percentage points higher than that in 2003. This process is accompanied by a large number of people gathering in the city, resulting in serious traffic congestion, which directly affects the travel experience of residents and reduces the commuting efficiency of residents. Some urban residents commute for 1~2 h a day, and the average commuting speed during peak hours is even lower than 10 km/h. The supply and demand ratio of parking spaces in the central area of the city has exceeded the level of 1:3. Therefore, the efficiency of transportation resource allocation has become an urgent problem to be solved. How to meet the growing diversified and high-frequency travel demand under limited resource constraints has become a crucial issue.

In recent years, national and local governments have introduced a series of transportation policies aimed at optimizing the allocation efficiency of transportation resources. The "Opinions of the General Office of the Central Committee of the Communist Party of China and the General Office of the State Council on Accelerating the Construction of a Unified and Open Transportation Market" (2025) explicitly calls for "optimizing the allocation of factor resources in the comprehensive transportation market" to promote the realization of "enjoyable travel for people and smooth flow of goods". It aims to enhance the overall efficiency of the transportation system through optimized factor allocation, thereby creating better conditions for residents' travel. As the material foundation supporting residents' mobility, transportation resources—and the efficiency with which they are allocated—not only affect the overall operational performance of the transportation system but also directly influence residents' travel utility and quality of life. Rational transportation resource allocation can promote coordinated development among different transportation modes, improve road resource utilization efficiency, reduce traffic congestion, and lower residents' travel time and costs. Against this backdrop, the relationship between transportation resource allocation efficiency and residents' travel utility has become a key research focus in academia and the field of urban planning and management. An in-depth investigation of this relationship will not only help clarify the intrinsic mechanisms through which transportation resource allocation affects residents' travel but also provide a scientific basis for formulating urban transportation planning and management policies, thereby promoting the development of urban transportation systems toward greater efficiency, sustainability, and human-centered design, and achieving the dual goals of optimizing resource allocation and maximizing residents' travel utility.

2. Literature Review

Existing research defines transportation resources in both broad and narrow senses. In the broad sense, transportation resources encompass the physical entities that constitute various modes of transport along with all external elements related to their operation. The allocation of these resources concerns the distribution—and, where applicable, preferential allocation—of human, financial, and material inputs across transport modes and regional systems. In the narrow sense, transportation resources refer to the carrying capacity provided for personal mobility and economic activity, manifested as the stock of transportation infrastructure accumulated across time and space. Scholars generally concur that transportation resource allocation efficiency denotes the optimal condition under which a given input of resources maximizes the output of transport services while meeting residents' travel demand. To measure resource allocation efficiency, data envelopment analysis (DEA) and its extensions—including the CCR model, the Malmquist index, the super-efficiency DEA model, and DEA-Bootstrap—are widely applied [1]. In terms of evaluation dimensions, Huang Ailing et al. constructed a three-dimensional allocation evaluation system—"transport capacity supply—travel demand—carbon emissions"—for integrated transportation hub scenarios, emphasizing the importance of coordinated allocation across multiple modes of transportation [2]. The allocation of transportation resources exerts a profound influence on economic development. As early as the eighteenth century, Adam Smith, in The Wealth of Nations, systematically elucidated the economic function of transport infrastructure, observing that "the prosperity of a country's commerce depends in a great measure upon good roads, bridges, canals, harbours, and other public works". On the one hand, improvements in transportation resource allocation can lower enterprise costs, enhance productivity, and boost total factor productivity in manufacturing. On the other hand, increased efficiency in resource allocation fosters regional economic integration; through the spatial spillover effects of transport infrastructure, it stimulates coordinated growth in adjacent regions, thereby narrowing regional disparities and promoting balanced economic development. Beyond traditional research on regional economic growth, Zhang Linling et al. focused on the interplay between government intervention and transportation resource allocation, pointing out that the expansion of transportation infrastructure resource allocation indirectly affects carbon emission levels, and that this effect exhibits significant threshold characteristics, thereby expanding the scope of research on the environmental impacts of transportation resource allocation [3]. At the same time, the rise of digital transportation has also driven innovation in resource allocation models. Wang Shuai et al. propose that big data and smart dispatching can optimize the allocation of spatiotemporal transportation resources and further enhance the precision of allocation, which has become an emerging direction in current research on transportation resource allocation [4].

A large body of theoretical literature indicates that transportation resource allocation plays an important role in improving the comfort as well as the feeling of safety of residents in their travel. Proper and efficient allocation would be able to markedly help residents achieve significant gains in terms of travel utility. Xanthopoulos et al.conducted research focused on shared transportation hubs and confirmed that there is a law of diminishing returns between transportation resource investment and travel utility [5]; once resource allocation reaches a certain threshold, the effect on utility improvement gradually weakens. From the residents' perspective, public transportation is associated with relatively small out-of-pocket expenditures. In comparison, private automotive travel does not only involve large initial and recurrent costs such as vehicle purchase, fuel, and parking fees, but also increasing costs during periods of congestion [6]. The proper allocation of transportation resources should thus aim to minimize the total cost of travel and maximize travel utility by optimizing the modal structure. According to a study conducted by Pucher and Buehler [7], if the road space is planned in advance and there are separate, continuous and visually attractive bike tracks and walking trails, the residents can have a more comfortable and enjoyable travel experience, which will be a contributing factor towards better quality of active movement. Reconfiguring the spatial and time distribution of transportation resources may alter the modal split, which will decrease system-level aggregate travel costs and ease congestion on the system. Concerning safety, the rational use of transportation resources could greatly decrease the number of traffic accidents and enhance the overall safety of mobility of residents [8].

However, despite numerous volumes of literature that have addressed transportation resource allocation and the travel behavior of the residents, the literature at hand exhibits several notable limitations. To begin with, many of the studies address the single-factor or localized resource allocation and largely overlooking the effect of the integrated transportation system efficiency on residential travel utility. Secondly, research on the mediating mechanism and boundary conditions through which resource allocation efficiency affects residents' travel utility remains inefficient, it is difficult to reveal the impact pathway between the two. The third one is that few studies have investigated different stages of urban development or different population sizes, which limits the generalizability of the current findings. In this study, it is planned to advance theoretical understanding in the following respects: First, it develops a comprehensive framework for evaluating transportation resource allocation efficiency. Infrastructure supply, labor, and capital investment constitute the input indicators whereas desirable and undesirable outputs constitute the output indicators. Secondly, it provides an explanation of the mechanisms by which transportation resource allocation efficiency enhances resident travel utility—namely, by promoting urbanization, mitigating environmental pollution and minimizing the number of fatalities due to accidents on the road; it also examines the mediating role of government intervention. Thirdly, it identifies the effective range of transportation resource allocation by accounting for the non-linear effect of transportation resource allocation efficiency on travel utility. The contributions are expected to enrich the theoretical connotation of transportation resource allocation and provide new perspectives for research in related fields.

3. Theoretical Analysis

3.1. Direct Impact of Transportation Resource Allocation Efficiency on Residents' Travel Utility

According to the theory of resource allocation in microeconomics, effective resource allocation may expand the boundary of production possibility, so as to improve the total social welfare. The effective allocation of resources in the transportation industry can optimize the input and output of transportation factors under limited infrastructure and resource constraints, thereby improving the operational efficiency of the transportation system. Accurate allocation of transportation resources to maximize the use of limited resources to meet the diverse travel needs of residents is also a guarantee for the sustainable development of the transportation system. In the context of cost-benefit analysis, the efficiency of traffic resource allocation has a significant impact on the marginal cost and marginal benefit of residents' travel. Effective allocation can also save travelers a lot of time, economic and psychological costs. Minimizing travel time allows residents to spend more time on other productive activities such as work and study, thereby saving time costs. More investment in public transport infrastructure and the introduction of bus lanes can enhance the structure of traffic patterns, thereby minimizing overall travel costs and increasing the cost-utility of travel, which directly increases the economic welfare of residents. At the same time, it is also possible to reduce the degree of traffic congestion and improve the quality of transfer, thus greatly reducing the psychological cost of residents' travel and improving the satisfaction of residents' travel. At the same time, the rational layout of traffic signs, markings, and safety measures can also minimize traffic accidents [8]. Based on the above analysis, the following hypotheses are proposed:

Hypothesis 1 (H1): *Transportation resource allocation efficiency positively enhances residents' travel utility.*

3.2. The Influence Path of Transportation Resource Allocation Efficiency on Residents' Travel Utility

The improvement of transportation resource allocation efficiency will inevitably promote the flow of production factors between regions. Enhanced transport infrastructure—such as highways and railways—has expanded the spatial scope of the city, thus attracting more industrial and population agglomeration [9]. At the same time, better transportation infrastructure promotes industrial agglomeration by improving inter-regional accessibility, thereby attracting more enterprises to enter these regions. With industrial agglomeration, employment opportunities have multiplied, attracting a large number of rural labor force to the city, further promoting the process of urbanization. The improvement of urbanization level has double benefits to residents' travel utility. On the one hand, it brings more comprehensive urban infrastructure and higher accessibility of public transport services [10], thereby diversifying travel choices, reducing travel time and cost, and improving overall comfort. On the other hand, urbanization has promoted the development of green mobility and eco-cities, increased per capita green space, and improved air quality. These environmental benefits can significantly improve the travel utility of residents. Based on this, this study proposes that the efficiency of transportation resource allocation can improve residents' travel utility by improving the level of urbanization.

Severe traffic congestion not only reduces the travel experience of residents, but also increases fuel consumption and pollutant emissions, thereby exacerbating environmental degradation. When the efficiency of transportation resource allocation is improved, the transportation network becomes more robust and the congestion is substantially alleviated. Vehicles running on efficient networks experience fewer stop-and-go cycles and maintain relatively stable speeds. This more stable driving mode promotes more complete fuel combustion in the vehicle's engine, thereby reducing exhaust emissions per unit travel distance. Studies have shown that improving the efficiency of transportation resource allocation can effectively alleviate environmental pollution. Li et al. found that optimizing transport mode split can reduce pollutant emissions and improve operational efficiency [11], thereby reducing the environmental footprint of transportation. It indicates that the optimal allocation of transportation resources can greatly reduce environmental pollution. Elevated concentrations of air pollutants pose a direct threat to public health. In contrast, reducing pollutant levels can improve air quality and minimize the inhalation of harmful particulate matter by residents during travel. The improvement of air quality has a good psychological impact on mobility and enhances the physiological experience of mobility. Better air quality also encourages green travel such as walking and cycling. These models can not only bring health benefits to people, enhance the flexibility and autonomy of travel, but also help to alleviate congestion and improve the overall efficiency of the system. Research by Khreis et al. shows that reducing emissions from the transport sector can produce significant economic [12], social and environmental co-benefits in addition to improving public health. Accordingly, this study proposes that the efficiency of transportation resource allocation can improve residents' travel utility by alleviating environmental pollution.

Effective traffic resource allocation can reasonably design road alignment, thereby reducing the risk of accidents caused by unsatisfactory road geometric conditions, such as vehicle out of control. Increasing investment in traffic safety infrastructure, including crash barriers and traffic signals, helps to guide vehicle movement and reduce the probability of collisions, thereby reducing the number of traffic-related deaths. Bolgato et al. pointed out that limiting the traffic volume of private cars and trucks, while limiting the overall capacity of motorized roads [13], is associated with a downward trend in traffic deaths. At the same time, the construction of dedicated infrastructure—such as bike lanes and pedestrian zones—and the implementation of traffic safety measures can enhance the safety of pedestrians and cyclists and further reduce the number of deaths. In addition to the improvement of infrastructure, the allocation of traffic resources is optimized by increasing the human resources input of the transportation department and fine road design, which further reduces the incidence of fatal accidents. These enhancement measures reduce the potential economic and security risks faced by residents in the process of travel, thus contributing to safer and more efficient travel. Based on the above analysis, the following hypotheses are proposed:

Hypothesis 2 (H2): *Transportation resource allocation efficiency enhances residents' travel utility by promoting urbanization, mitigating environmental pollution, and reducing traffic accident fatalities*.

3.3. Moderating Effect of Government Intervention on the Relationship between Transportation Resource Allocation Efficiency and Residents' Travel Utility

The government's intervention in the transportation sector is mainly reflected through policy formulation and resource allocation. Excessive regulation may stifle market vitality and innovation, thereby reducing the efficiency of resource allocation. Over-reliance on government subsidies and infrastructure investment can lead to resource misallocation and hinder the efficient operation of transportation systems. In areas such as public transport operations and transport infrastructure investment, market participants are often able to allocate resources efficiently according to demand signals and efficiency requirements. However, when the government intervenes excessively, it will limit the independent decision-making space of the market participants and may make the allocation of resources deviate from its optimal state. Studies have shown that when the proportion of local government fiscal expenditure in GDP is too high, the efficiency of resource allocation tends to decline, which has a negative impact on broader economic development. In addition, government intervention may lead to resource misallocation. When allocating transportation resources, government agencies may be affected by political and administrative factors, as well as other non-market factors, thereby shifting key resources to priority projects that are critical to improving resource allocation efficiency and residents' travel utility. This distortion weakens the positive impact of effective resource allocation on travel utility. Based on the above analysis, the following hypotheses are proposed:

Hypothesis 3 (H3): *Government intervention negatively moderates the effect of transportation resource allocation efficiency on residents' travel utility.*

4. Empirical Design

4.1. Model Construction

4.1.1. Baseline Model

To examine the impact of transportation resource allocation efficiency on residents' travel utility, this study specifies the following fixed-effects model:

$$Resi_{i,t} = \alpha + \alpha_1 Eff_{i,t} + \alpha_2 Controls_{i,t} + \lambda_i + \varepsilon_{i,t} \tag{1}$$

where *i* indexes cities, *t* indexes years, $Resi_{i,t}$ denotes the travel utility of residents in city *i* in year *t*, and $Eff_{i,t}$ represents the transportation resource allocation efficiency of city *i* in year *t*. $Controls_{i,t}$ is a vector of control variables, α is the constant term, λ_i captures individual fixed effects, and $\varepsilon_{i,t}$ is the random error term.

4.1.2. Mediation Model

To verify the hypothesized transmission mechanism—namely, that transportation resource allocation efficiency affects residents' travel utility through the level of urbanization, the degree of environmental pollution, and the number of traffic accident fatalities—this study follows established recommendations for mediation testing and constructs the following mediation model based on Equation (1):

$$Mediator_{i,t} = \theta + \rho Eff_{i,t} + \gamma Controls_{i,t} + \lambda_i + \varepsilon_{i,t} \tag{2}$$

where $Mediator_{i,t}$ denotes the mediating variables, specifically the level of urbanization, the degree of environmental pollution, and the number of traffic accident fatalities. θ is the intercept, and the coefficient ρ captures the effect of the explanatory variable $Eff_{i,t}$ on the mediator. A positive ρ indicates that transportation resource allocation efficiency promotes the mediator, whereas a negative coefficient suggests the opposite. If α_1 in Equation (1) is statistically significant and ρ in Equation (2) is likewise significant, the presence of a mediating effect is supported.

4.1.3. Moderation Model

To further examine whether the impact of transportation resource allocation efficiency on residents' travel utility is contingent upon the degree of government intervention, this study introduces government intervention (*GI*) as a moderating variable and constructs the following moderation model:

$$Resi_{i,t} = \omega_0 + \omega_1 Eff_{i,t} + \omega_2 GI_{i,t} + \omega_3 Eff_{i,t} \times GI_{i,t} + \omega_4 Controls_{i,t} + \lambda_i + \varepsilon_{i,t} \tag{3}$$

where ω_0 is the constant term; ω_1 is the coefficient to be estimated for the explanatory variable; ω_2 is the coefficient for the moderating variable; and ω_3 is the coefficient for the interaction term. If both ω_1 and ω_3 are statistically significant, a moderating effect is indicated. If ω_1 and ω_3 share the same sign, the moderator positively reinforces the relationship; opposite signs indicate a negative moderating effect.

4.1.4. Threshold Model

To examine the potential threshold effects in the relationship between transportation resource allocation efficiency and residents' travel utility, this study employs transportation resource allocation efficiency (Eff) as the threshold variable and constructs the following threshold regression model:

$$Resi_{i,t} = \beta_0 + \beta_1 Eff_{i,t} \times I_{i,t}(q \leq \delta) + \beta_2 Eff_{i,t} \times I_{i,t}(q > \delta) + \beta_3 Controls_{i,t} + \lambda_i + \varepsilon_{i,t} \tag{4}$$

where $I(.)$ is the indicator function, δ is the threshold value to be estimated, and q denotes the threshold variable.

4.2. Variable Definitions

4.2.1. Dependent Variable

The dependent variable is residents' travel utility (Resi). Drawing on existing methodologies [14], this study employs the entropy method for its measurement. Regarding specific indicators, based on prior research and the scope of this study, seven indicators across four dimensions—safety, environment, efficiency, and economy—are selected to measure residents' travel utility. The specific indicators are presented in Table 1.

Table 1. Indicator system for measuring the dependent variable.

Primary Indicator	**Secondary Indicator**	**Measurement Method**	**Direction**
Safety	Traffic accident rate per capita	Number of traffic accidents/Permanent resident population	Negative
	Traffic fatality rate per capita	Number of traffic fatalities/Permanent resident population	Negative
Environment	Energy consumption per unit of transport GDP	Total transport energy consumption/Transport sector GDP	Negative
Efficiency	Car ownership per capita	Car ownership/Permanent resident population	Positive
	Road area growth rate	(Current road area-Previous road area)/Previous road area	Positive
	Average one-way travel time	-	Negative
Economy	Average one-way travel cost	Average commuting time * Wage rate	Negative

Note: Average one-way travel cost is calculated by multiplying average one-way travel time by the local wage rate.

4.2.2. Explanatory Variable

The explanatory variable is transportation resource allocation efficiency (Eff). Following established practices, this study adopts the super-efficiency SBM model. This model improves upon traditional DEA models by allowing efficiency scores to exceed 1 and by accounting for undesirable outputs in the production process, thus aligning more closely with real-world conditions.

Transportation resource allocation efficiency involves economic, social, and environmental dimensions, and the selection of indicators must comprehensively cover these aspects. Based on a synthesis of prior research [15], this study selects road area, number of public transport vehicles in operation, number of employees, and fixed-asset investment in roads and bridges as input indicators. Total urban passenger volume serves as the desirable output indicator, while CO_2 emissions are treated as the undesirable output indicator. The input-output indicators for the super-efficiency SBM model are detailed in Table 2.

Table 2. Indicator system for measuring the explanatory variable.

Input-Output System Category Indicator Specific Measure	Input Indicators	Investment in infrastructure	Road area
			Number of public transport vehicles in operation
		System operation cost investment	Number of employees
			Fixed-asset investment in roads and bridges
	Output Indicators	Desirable Output	Total urban passenger volume
		Undesirable Output	CO_2 emissions

4.2.3. Control Variables

To enhance the precision of the analysis, this study draws on relevant literature and the research context to select six control variables: population density, economic development level, degree of openness, industrial structure upgrading, social consumption level, and government self-sufficiency.

Population density (lnDen) refers to the number of resident population per unit land area, which is measured by the natural logarithm of the ratio of resident population to land area. In areas with high population density, travel demand tends to be more concentrated and diversified. High-density areas usually require more efficient traffic resource allocation to meet the travel needs of a large number of people; otherwise, it is easy to cause traffic congestion and other problems, which will have a negative impact on the travel utility of residents.

The level of economic development (pGDP) is measured by per capita GDP. By incorporating the level of economic development as a control variable into the analysis, the confounding effects of different economic development stages on the efficiency of traffic resource allocation and residents' travel utility can be excluded, so as to more clearly examine the impact of traffic resource allocation efficiency itself on residents' travel utility.

Openness (Open) is measured by the ratio of total import and export trade to regional GDP. Areas with higher openness tend to have more migrants and more international exchange activities, resulting in a more complex structure of travel demand and higher requirements for the internationalization and convenience of transportation services. At the same time, regions with greater openness are also more likely to introduce advanced transportation technology and management practices, thereby improving the efficiency of transportation resource allocation.

Industrial structure upgrading (Indus) is measured by the ratio of the added value of the tertiary industry to the added value of the secondary industry. The secondary industry, which is dominated by manufacturing, has produced a large number of employees' commuting needs and cargo transportation needs. The tertiary industry, which is dominated by the service industry, is often accompanied by the improvement of urban infrastructure and the optimization of transportation services. The upgrading of industrial structure will cause changes in the spatial and temporal distribution of travel demand, which will affect the efficiency of traffic resource allocation and residents' travel utility.

The level of social consumption (Consum) is measured by the ratio of total retail sales of social consumer goods to regional GDP. In areas with high levels of social consumption, residents have stronger consumption capacity for transportation services, and may be more inclined to choose high-quality and personalized travel methods. In addition, a higher level of consumption will also encourage transportation companies to improve service quality and resource allocation efficiency to meet market demand.

Government self-sufficiency (Suff) is measured by the ratio of general public budget revenue to general public budget expenditure. Areas with strong government self-sufficiency can allocate more funds to the construction and maintenance of transportation infrastructure, thereby improving the efficiency of transportation resource allocation.

4.2.4. Mediating Variables

The level of urbanization (urban) is measured by the proportion of urban resident population to the total resident population. Analyzing the impact of urbanization level on residents' travel utility can provide a scientific basis for coordinating transportation planning and urbanization strategy in practice, so as to help improve the level of urbanization and improve the overall traffic welfare of society.

The number of traffic accident deaths (Death) is measured by the number of traffic accident deaths per 10,000 people. The higher number of deaths reflects the potential problems in the allocation and management of regional traffic resources, prompting the government to take more robust measures to improve the allocation of traffic resources, so as to improve the utility of residents' travel.

The degree of environmental pollution (PM2.5) is represented by the concentration of PM2.5. PM2.5 concentration is a key indicator to measure environmental pollution, and transportation activities constitute one of the main sources of PM2.5. Therefore, this study uses PM2.5 concentration to characterize the degree of environmental pollution. By analyzing the relationship between environmental pollution and traffic resource allocation, we can understand the dual impact of traffic activities on the environment and public health more deeply.

4.2.5. Moderating Variable

Government intervention (GI) is measured by the ratio of government fiscal expenditure to gross regional product. This variable is selected as the moderator because the effect of transportation resource allocation efficiency on residents' travel utility is likely to be conditioned by government behavior and policy orientation.

4.3. Data Sources and Descriptive Statistics

Considering data availability and completeness, this study employs panel data from 162 prefecture-level cities in China covering the period 2003–2022. Data are sourced from statistical yearbooks of various prefecture-level cities, the China Economic Information Network statistical database, CBN Weekly, Baidu Maps statistical reports, and questionnaire surveys. Missing data for individual cities in specific years were supplemented using linear interpolation. Descriptive statistics for all variables are presented in Table 3.

Table 3. Descriptive statistics of variables.

Variable	Symbol	Observations	Mean	Std. Dev.	Min	Max
Residents' Travel Utility	Resi	3240	0.181	0.084	0.076	0.949
Transportation Resource Allocation Efficiency	Eff	3240	0.493	0.424	0.002	2.868
Population Density	lnDen	3240	7.781	0.751	4.533	9.908
Economic Development Level	pGDP	3240	4.878	3.528	0.259	25.506
Degree of Openness Open	Open	3240	0.283	0.435	0.000	4.622
Industrial Structure Upgrading Indus	Indus	3240	0.965	0.53	0.149	5.419

Table 3. *Cont*.

Variable	Symbol	Observations	Mean	Std. Dev.	Min	Max
Government Self-Sufficiency Suff	Suff	3240	0.547	0.227	0.061	1.541
Social Consumption Level Consum	Consum	3240	0.372	0.123	0.026	3.835
Urbanization Level urban	urban	3240	0.552	0.180	0.113	1.000
Environmental Pollution Degree PM2.5	PM2.5	3220	43.857	15.405	12.843	104.863
Traffic Accident Fatalities Death	Death	3240	0.578	0.552	0.007	15.633
Government Intervention	GI	3240	0.151	0.069	0.041	0.675

5. Empirical Results and Analysis

5.1. Baseline Regression

In order to investigate the impact of transportation resource allocation efficiency on residents' travel utility, Model (1) is estimated. The regression results are shown in Table 4. Column (1) reports the results without control variables, showing that the coefficient of residents' travel utility is positive and statistically significant at the level of 1%. This finding is consistent with the theoretical expectations of new economic geography on accessibility improvement and resource optimization [16]. Column (2) gives the results containing control variables; the coefficient is still positive and significant at the level of 5%, indicating that the efficiency of traffic resource allocation has significantly improved the travel utility of residents. Among the control variables in Column (2), the level of economic development and the upgrading of industrial structure have a significant positive impact on travel utility, which is in line with the logic of economic growth driving traffic demand upgrading. Economically developed regions usually have strong financial capacity for sustained infrastructure investment, and industrial upgrading often requires higher frequency and time-sensitive travel demand, forcing the allocation of transportation resources to develop in a more efficient direction. On the contrary, government self-sufficiency has a significant negative impact on travel utility. This may reflect that fiscally autonomous regions tend to prioritize short-term, high-return economic projects rather than public service-oriented investment, so that resource allocation deviates from facilities that directly improve residents' travel utility.

Table 4. Baseline regression results.

Variable	(1)	(2)
Transportation Resource Allocation Efficiency	0.157 ***	0.030 **
	(12.848)	(2.599)
Population Density		−0.002
		(−0.764)
Economic Development Level		0.016 ***
		(16.088)
Degree of Openness		0.005
		(0.487)
Industrial Structure Upgrading		0.047 ***
		(5.341)
Government Self-Sufficiency		−0.093 ***
		(−5.028)
Social Consumption Level		0.015
		(0.732)
Constant	0.104 ***	0.101 ***
	(17.292)	(4.120)
Individual Fixed Effects	Fixed	Fixed
Observations	3240	3240
R^2	0.328	0.681

Note: ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively. *t*-statistics are in parentheses.

5.2. Robustness Tests

In order to test the robustness of the benchmark regression results, this paper adopts three methods to test the robustness of the explanatory variables lag one period, eliminate the municipalities directly under the central government, and shrink the tail. The specific estimation results are shown in Table 5. Considering that there is a certain time difference when the allocation efficiency of traffic resources affects the travel utility of residents, the explanatory variables are lagged by one period for robustness test. The results are shown in Column (1), and the lag term of traffic resource allocation efficiency is significantly positive at the 1% level. Because municipalities have greater autonomy and flexibility in policy formulation and resource allocation, which may lead to significant differences in traffic resource allocation and residents' travel utility compared with other regions, municipalities are excluded for robustness test. The results are shown in Column (2). The efficiency of traffic resource allocation is significantly positive at the 5% level, which enhances the robustness of the research conclusions. In order to avoid the great influence of extreme values on the regression results, which leads to the inaccurate estimation of the regression coefficient, the data is tailed up and down by 1%. The results show that in column (3), the efficiency of traffic resource allocation is significantly positive at the 1% level. In summary, the regression coefficients of the core explanatory variables of various test methods are significantly positive, which is consistent with the benchmark regression results, indicating that the research conclusions in this paper have strong robustness.

To address the potential endogeneity of the model, this paper adopts the instrumental variable method and selects urban topographic relief as the instrumental variable. As an inherent geographical endowment, terrain conditions directly determine the difficulty of transportation infrastructure construction and resource allocation, and are not affected by residents' travel behavior and travel demand. To adapt to the panel fixed-effect model, this paper constructs a time-varying instrumental variable by interacting topographic relief with the time trend term. The regression results of the instrumental variable method are reported in the Table 6. The results of the first-stage regression show that the coefficient of the instrumental variable is significantly positive at the 1% statistical level, which verifies a valid correlation between the instrumental variable and the endogenous variable. In the second-stage regression, the Kleibergen-Paap rk LM statistic has a p-value of 0.0000 and is significant at the 1% level, rejecting the null hypothesis and confirming that the model suffers from no under-identification. Both the Cragg-Donald Wald F statistic and the Kleibergen-Paap rk Wald F statistic are substantially higher than the Stock-Yogo critical values, indicating a strong correlation between the instrumental variable and the endogenous variable and excluding the problem of weak instrumental variables. The above tests fully verify the rationality of the selected instrumental variable. Meanwhile, the coefficient of the core explanatory variable remains significantly positive in the two-stage regression, which further supports Hypothesis 1 of this study.

Table 5. Robustness tests.

	(1)	**(2)**	**(3)**
Variable	**Lagged Explanatory Variable**	**Excluding Municipalities**	**Winsorized Data**
Transportation Resource Allocation Efficiency Transportation Resource Allocation Efficiency (Lagged)	0.034 ***	0.023 ** (2.089)	0.029 *** (3.058)
Control Variables	(3.147) Controlled	Controlled	Controlled
Constant	0.096 ***	0.092 ***	0.082 ***
Individual Fixed Effects	(3.732) Fixed	(4.112) Fixed	(3.267) Fixed
Observations	3078	3160	3240
R^2	0.710	0.703	0.737

Note: ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively. *t*-statistics are in parentheses.

Table 6. Endogeneity tests.

	(1)	**(2)**
Variable	**Transportation Resource Allocation Efficiency**	**Residents' Travel Utility**
Transportation Resource Allocation Efficiency		0.105 ***
		(2.760)
Instrumental variable	0.014 ***	
	(4.260)	
K-PLMstat		21.815
C-DF-stat		222.438
K-PF-stat		18.149
Pvalue		0.006
Control Variables	Controlled	Controlled
Individual Fixed Effects	Fixed	Fixed
Observations	3240	3240
R^2	0.0675	0.6339

Note: ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively. *t*-statistics are in parentheses.

5.3. Heterogeneity Analysis

To investigate heterogeneity in the impact of transportation resource allocation efficiency on residents' travel utility, the 162 cities are categorized into first-tier, second-tier, and third-tier-and-below cities based on the "2023 City Business Attractiveness Ranking" published by CBN Weekly. This classification is chosen because systematic hierarchical differences exist across city tiers in terms of development factors, resource allocation characteristics, and residents' travel behavior. First-tier cities, as economic and population hubs, face complex travel demands and intense resource allocation pressures; second- and third-tier cities are at different developmental stages, with varying spatial structures and infrastructure intensities. Analyzing across these tiers ensures comprehensive coverage of transportation system scenarios and provides a basis for targeted policy formulation.

The results are shown in Table 7. The coefficients of the first-tier and second-tier urban traffic resource allocation efficiency are 0.086 and 0.057, respectively, which are significant at the level of 1%. This shows that the improvement of efficiency has significantly enhanced the travel utility of these cities, and this effect is more obvious in first-tier cities. In contrast, the coefficients of third-tier and below cities are not statistically significant, indicating that their impact can be ignored. This difference may be due to higher population density and more complex economic activities in high-level cities, and the benefits of optimizing resource allocation in alleviating congestion and improving convenience are greater. In addition, higher-level cities usually receive more policy support and resource investment for infrastructure construction. On the contrary, lower-level cities tend to have less developed transportation infrastructure and simpler travel demand patterns, resulting in insignificant impact of resource optimization on travel utility.

Table 7. Heterogeneity analysis.

	(1)	(2)	(3)
Variable	**First-Tier Cities**	**Second-Tier Cities**	**Third-Tier-and-Below Cities**
Transportation Resource Allocation Efficiency	0.086 ***	0.057 ***	0.016
Control Variables	(4.038) Controlled	(3.046) Controlled	(1.274) Controlled
Constant	0.063	−0.014	0.094 ***
Individual Fixed Effects	(0.778) Fixed	(−0.230) Fixed	(4.079) Fixed
Observations	360	520	2360
R^2	0.865	0.847	0.629

Note: ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively. *t*-statistics are in parentheses.

5.4. Mechanism Tests

5.4.1. Mediation Effect Test

To test the mediating roles of urbanization level, environmental pollution degree, and traffic accident fatalities in the relationship between transportation resource allocation efficiency and residents' travel utility, Model (2) is estimated. The results are presented in Table 8.

Column (1) shows that the coefficient of traffic resource allocation efficiency to urbanization level is positive and significant at the level of 1%. Transportation infrastructure is a fundamental driver of urban expansion and factor agglomeration. Efficient transportation resource allocation optimizes the connectivity between urban functional areas, reduces cross-regional commuting and transaction costs, and substantially enhances a city's capacity to attract industrial projects and labor force. Efficient transportation networks have significantly reduced transportation and transaction costs and have become a powerful force to attract population and industries to cities. The improvement of resource efficiency is conducive to smoother interaction between enterprises and more efficient flow of goods, promote the coordinated development of industries, and attract rural labor into cities. Domestic research has confirmed that the improvement of the quality of transportation infrastructure is related to the higher urbanization rate. With the continuous advancement of urbanization, urban public service systems and transportation supporting facilities are further improved, public transport coverage and service accessibility are continuously enhanced, residents' travel options become more diversified, and travel time and economic costs are effectively cut down. Therefore, by promoting urbanization, the improvement of resource allocation efficiency has expanded the attractiveness and radiation capacity of cities, enriched employment, education and medical resources, and thus improved the effectiveness of residents' commuting, shopping and social activities.

Column (2) reports that the influence coefficient of traffic resource allocation efficiency on environmental pollution is −5.695, which is significant at the level of 1%. Consistent with environmental economics, efficient transport systems play a crucial role in reducing energy consumption and pollutant emissions. Inefficient transportation resource allocation often leads to unbalanced road network layout, frequent traffic congestion and repeated vehicle start-stop, which greatly increases fuel consumption and exhaust emissions represented by PM2.5. In contrast, optimized resource allocation rationalizes traffic flow distribution, smooths vehicle operating speed, and realizes full combustion of vehicle fuel, thereby fundamentally curbing the generation of traffic-related pollutants. A well-planned transportation network reduces unnecessary vehicle driving and idle time, and reduces fuel consumption and exhaust emissions. Advanced traffic management systems can optimize traffic flow, alleviate congestion, and further curb energy waste and pollution, thereby improving air quality. The improvement of air quality is directly beneficial to the health and quality of life of residents, because breathing cleaner air during travel can reduce health risks and undeniably improve travel utility. Better atmospheric environment also encourages residents to choose green travel modes such as walking and cycling, forming a virtuous cycle between transportation optimization, environmental improvement and travel experience upgrading.

Column (3) presents the mediating test results of the number of deaths in traffic accidents. The coefficient of traffic resource allocation efficiency is −0.115, which is significant at the level of 5%, which confirms that the improvement of efficiency reduces the number of deaths, thus improving the travel utility. Effective resource allocation includes reasonable road design, perfect transportation facilities and scientific traffic management. The optimization of transportation resources covers not only the stock expansion of infrastructure, but also the refined allocation of safety facilities, road signs and human management resources. Scientific road geometric design eliminates potential safety hazards such as sharp curves and steep slopes, while complete traffic signal facilities and standardized traffic management regulate the travel behavior of motor vehicles, non-motor vehicles and pedestrians. Reasonable road design can reduce security risks; clear signs and functional signals guide orderly movement; and effective management, reduce traffic violations. These factors together reduce the probability and severity of the accident and reduce the number of deaths. With more reliable protection of life and limbs during travel, residents' perceived safety and psychological security are significantly enhanced, thereby significantly improving travel effectiveness. From the perspective of travel utility, the reduction of traffic accident fatalities eliminates residents' travel safety concerns, elevates travel comfort and psychological satisfaction, and ultimately realizes the improvement of overall travel utility. Therefore, hypothesis 2 is supported.

Table 8. Mediation mechanism tests.

	(1)	**(2)**	**(3)**
Variable	**Urbanization Level**	**Environmental Pollution Degree**	**Traffic Accident Fatalities**
Transportation Resource Allocation Efficiency	0.076 ***	−5.695 ***	−0.115 **
Control Variables	(5.015) Controlled	(−5.094) Controlled	(−2.153) Controlled
Constant	0.369 ***	44.102 ***	1.179 ***
Individual Fixed Effects	(7.333) Fixed	(11.046) Fixed	(4.748) Fixed
Observations	3240	3220	3240
R^2	0.551	0.318	0.178

Note: ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively. *t*-statistics are in parentheses.

5.4.2. Moderation Effect Test

In order to further test whether the impact of traffic resource allocation efficiency on residents' travel utility is regulated by government intervention, the adjustment model (3) is estimated. The results are shown in Table 9. Column (1) repeats the baseline results, while Column (2) presents a moderating regression. In column (2), the efficiency of transportation resource allocation and its interaction with government intervention are significant at the level of 1%. However, the coefficient of the interaction term is −0.249, which is contrary to the main effect symbol of efficiency. This shows that government intervention negatively regulates this relationship: with the increase of government intervention, the effect of resource allocation efficiency on travel utility is weakened.

In the process of transportation resource allocation, excessive government intervention may make resource allocation deviate from the optimal state. The government's decision-making may be affected by political factors, information asymmetry, etc., and it is impossible to accurately grasp the market demand and the best allocation of resources. For example, when planning transportation projects, the government may give priority to the construction of some image projects due to performance considerations, rather than projects that truly meet the travel needs of residents, resulting in limited transportation resources not being used reasonably. In this case, although the government has invested a lot of resources for transportation construction, due to the reduction of resource allocation efficiency, the improvement effect of transportation resource allocation efficiency on residents ‘ travel utility is weakened. There is a reverse adjustment phenomenon that the greater the degree of government intervention, the smaller the improvement effect of transportation resource allocation efficiency on residents' travel utility. Parry & Small proved that when the bus subsidy exceeds 30% [17], every 10% increase in subsidy will lead to a 6–8% decrease in resource allocation efficiency. Through the study of subway fares in 35 cities in China, Li et al. found that when the fare is lower than 50% of the cost price, the congestion cost will offset the welfare gain [18]. Therefore, when formulating transportation policies, the government needs to balance market mechanism and administrative intervention to ensure the efficiency and fairness of resource allocation.

Table 9. Moderation effect test.

Variable	(1)	(2)
Transportation Resource Allocation Efficiency	0.030 **	0.067 ***
	(2.599)	(3.597)
Government Intervention		0.404 ***
		(4.431)
Interaction Term		−0.249 ***
		(−3.756)
Control Variables	Controlled	Controlled
Constant	0.101 ***	0.046 *
	(4.120)	(1.712)
Individual Fixed Effects	Fixed	Fixed
Observations	3240	3240
R^2	0.681	0.696

Note: ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively. *t*-statistics are in parentheses.

5.5. Further Analysis: Threshold Effect

Traditional research often assumes a simple positive linear relationship between transportation resource input and travel utility. In reality, resource allocation is subject to diminishing marginal returns and phase-specific threshold effects. When input is below a critical value, each additional unit significantly boosts utility; beyond the threshold, marginal utility may weaken or even become negative. Investigating threshold effects enables the precise identification of the effective operational range of resource allocation, preventing inefficient waste from blind investment and maximizing travel utility. Therefore, building on the finding of a significant positive impact, this study further analyzes potential threshold effects.

First, the existence of panel thresholds is tested using the Bootstrap method with 300 replications to verify statistical significance. Table 10 reports the results for single, double, and triple threshold tests with transportation resource allocation efficiency as the threshold variable. The results indicate that both the single and double threshold models are significant at the 5% level, while the triple threshold is not. Thus, a double-threshold model is identified as appropriate. Table 11 presents the estimated threshold values and their confidence intervals. The first threshold value is estimated at 0.1444, and the second at 1.0537.

Table 10. Threshold effect significance tests.

Model	*F*-Statistic	*P*-Value	Bootstrap Replications	Critical Values		
				1%	5%	10%
Single Threshold	52.28	0.0167 **	300	58.4300	44.3214	38.5576
Double Threshold	37.06	0.0267 **	300	39.8775	31.5360	26.6643
Triple Threshold	14.00	0.4333	300	37.7195	29.9360	24.4468

Note: ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively. *t*-statistics are in parentheses.

Table 11. Threshold estimates and confidence intervals.

Threshold	Estimate	95% Confidence Interval
First Threshold	0.1444	[0.1371,0.1482]
Second Threshold	1.0537	[1.0234,1.0656]

Next, the threshold regression Model (4) is estimated, with results shown in Table 12. The impact of transportation resource allocation efficiency on residents' travel utility varies distinctly across different efficiency intervals. When efficiency is below the first threshold (0.1444), the coefficient is −0.115, indicating a negative impact on travel utility. When transportation resource allocation efficiency is below the first threshold (0.1444), inadequate infrastructure, unreasonable road network and flawed management create a mismatch between transport supply and travel demand. This worsens congestion, raises travel time and costs, and aggravates safety risks and exhaust pollution, thereby reducing residents' travel utility. After crossing the threshold, resources and system operations are optimized, and the efficiency starts to positively improve travel utility. At this stage, lagging infrastructure development and irrational resource allocation render the transportation system inefficient and incapable of meeting residents' travel demands. Once efficiency enters the second interval (0.1444 ≤ Eff < 1.0537), the coefficient becomes 0.0556, with a significantly enhanced positive effect. Here, resource allocation is more rational, coordination across regions and modes improves, and infrastructure development yields tangible benefits in network completeness and service convenience. However, when efficiency exceeds 1.0537, although the impact remains significantly positive, the coefficient drops to 0.0339, reflecting diminishing marginal returns. At this advanced stage, further improvements yield progressively smaller gains in travel utility. This underscores the need to adjust resource allocation strategies according to the prevailing efficiency level to maximize residents' travel utility.

Table 12. Threshold regression results.

	(1)	**(2)**
Variable	**Baseline Regression**	**Threshold Regression**
Eff	0.030 **	
	(2.599)	
Eff < 0.1444		−0.115 ***
		(0.0379)
0.1444 ≤ Eff < 1.0537		0.0556 ***
		(0.0160)
Eff ≥ 1.0537		0.0339 ***
		(0.0114)
Control Variables	Controlled	Controlled
Observations	3240	3240
Number of Cities	162	162
R^2	0.681	0.689

Note: ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively. *t*-statistics are in parentheses.

6. Conclusions and Policy Recommendations

This paper studies 162 Chinese cities from 2003 to 2022. Firstly, the super-efficiency SBM model is used to measure the efficiency of traffic resource allocation, and the entropy method is used to measure the residents' travel utility. Then, it empirically examines the impact, mechanism and threshold of the efficiency of transportation resource allocation on residents' travel utility, as well as the moderating effect of government intervention. The empirical results show that: First, the improvement of transportation resource allocation efficiency has effectively improved the travel utility of residents. Second, regarding the underlying mechanisms, urbanization level, PM2.5 concentration, and traffic accident fatalities all serve as significant mediators in this relationship, while government intervention attenuates the positive impact. Third, the enhancement effect exhibits heterogeneity across city tiers: it is significant in first- and second-tier cities but not in third-tier-and-below cities. Fourth, a double-threshold effect exists in the impact of efficiency on travel utility. When efficiency falls below the first threshold, it inhibits travel utility; when it lies between the first and second thresholds, the enhancement effect is most pronounced; and when it exceeds the second threshold, the effect, though still significant, diminishes markedly compared to the second interval.

The above conclusions have important implications for optimizing the allocation of transportation resources and improving the utility of residents' travel in China. Based on this, this study puts forward the following suggestions: First, the allocation of transportation resources should be dynamically adjusted according to the local development model. For first- and second-tier cities, priority should be given to continued investment in transport infrastructure. It includes expanding the rail transit network (such as subway, light rail, etc.) and optimizing the layout of bus lines to improve public transport coverage and service frequency. Using big data technology for real-time traffic monitoring and adaptive signal control can further alleviate congestion. In view of urban heterogeneity, implement tiered governance: for first- and second-tier cities with significant policy effects, priority should be given to continued investment in transport infrastructure. It includes expanding the rail transit network (such as subway, light rail, etc.) and optimizing the layout of bus lines to improve public transport coverage and service frequency. Using big data technology for real-time traffic monitoring and adaptive signal control can further alleviate congestion. For third-tier-and-below cities with insignificant effects of resource allocation efficiency, focus on improving basic transportation facilities rather than blind large-scale infrastructure investment, and focus on guaranteeing residents' basic travel needs. Second, urbanization and traffic development should be coordinated, and environmental quality and traffic safety should be improved simultaneously. Urban planning should pay attention to the coordinated development of transportation and land use, reduce the separation of jobs and residence, and shorten the commuting distance. Strengthening environmental pollution control and reducing PM2.5 concentration can improve travel comfort. At the same time, strong traffic safety management—by strengthening public awareness campaigns and improving transport facilities—is critical to reducing deaths. Third, reduce excessive administrative intervention in the transportation market and let the market play a decisive role. The introduction of competition mechanism in the fields of bus line approval and operation authority distribution can improve service quality and efficiency. The role of the government should be changed to guide, supervise and regulate the industry to ensure market order and operational safety. Fourth, the input of transportation resources should be accurately calibrated according to the existing efficiency level. When efficiency is below the first threshold, key constraints—such as infrastructure gaps or management deficiencies—must be identified and addressed. When efficiency falls within the optimal second interval, existing advantages should be consolidated and expanded. When the efficiency exceeds the second threshold, it is necessary to pay close attention to the diminishing marginal revenue and adjust the strategy in time to maintain a positive impact on residents' travel utility. This method can not only avoid the inefficiency caused by insufficient distribution, but also avoid the diminishing returns caused by excessive distribution, so as to ensure that the residents' travel utility is maximized within the optimal efficiency range.

7. Research Limitations and Future Research Prospects

Due to data availability constraints, this study does not delve into micro-level data at the district, county, or neighborhood levels, making it difficult to reflect spatial variations in the allocation of urban transportation resources and travel experiences. Additionally, the study does not distinguish between different modes of travel—such as public transportation, private vehicles, and non-motorized transport—and thus cannot identify the varying impacts of these modes. Furthermore, the study does not employ spatial econometric methods, thereby overlooking the spatial spillover effects generated by the interconnectivity of urban transportation networks. Future research could be improved in the following ways: First, expand the research scale by integrating macro-level statistical data with micro-level survey data and big data to conduct detailed studies from the perspectives of communities and neighborhoods. Second, distinguish between different modes of travel to compare and analyze the varying impacts of transportation resource allocation on each mode. Third, adopt spatial econometric models to explore the interdependent effects of transportation resource allocation and pathways for collaborative governance from the perspective of urban agglomerations.

Author Contributions

Y.M.: conceptualization, software, investigation, writing—original draft preparation; Y.T.: data curation, translation, formal revision; K.L.: supervision, writing—reviewing and editing, validation. All authors have read and agreed to the published version of the manuscript.

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The raw statistical data used in this study are publicly available from official statistical yearbooks and government open-access databases. Restrictions apply to the availability of these data, which were used under license for this research and cannot be shared publicly due to the data copyright.

Conflicts of Interest

The authors declare no conflict of interest.

Use of AI and AI-Assisted Technologies

No AI tools were utilized for this paper.

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