

Research Article

Sizing Up Transport Poverty Alleviation: A Structural Equation Modeling Empirical Analysis

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The aim of this paper was to systematically obtain the poverty reduction effects and diversified poverty alleviation paths of road infrastructure, to assist in the planning of transport poverty alleviation and rural revitalization in the concentrated contiguous poverty-stricken areas. The measurement methods for impact effects and paths of transport poverty alleviation have been scientifically proposed based on methods of transportation economics and transportation geography. Firstly, an overview of the interactive mechanism and processes by which road infrastructure investment influences poverty reduction has been offered, and the characteristics of poverty space and spatial coupling result of road infrastructure have been systematically obtained. The results show that about 70% of the district counties' road infrastructure and poverty rate are in a state of spatial coupling imbalance; the coordinated synchronous type is mainly distributed along the road network. Secondly, the structural equation model system has been formulated with variables that reflect transportation input in adjacent geographical units to consider spatial spillover effects. The results show that the direct poverty reduction effect of road infrastructure (0.105) is much lower than the indirect poverty reduction effect (0.830). Thirdly, empirical analysis at regional level of the concentrated contiguous poverty-stricken areas in China has been conducted. As a result, while addressing the limitations of previous studies, the poverty alleviation path that has been proposed also aims to catalyze actions to reduce the transport-related exclusion in poverty-stricken areas caused by the lack of access to basic facilities.

1. Background

Poverty is a global development problem and a practical problem. Antipoverty has become an important issue facing all mankind, especially developing countries, where poverty has seriously restricted the coordinated development of social economy [1]. One of the largest and most comprehensive surveys about poverty published to date is the "Voices of the Poor," which summarized 40,000 experiences of poor people from 50 different countries around the world. The findings of this report assert that poverty is perceived as consisting of many interlocking dimensions, in which lack of access to basic infrastructure, rural roads, and transportation is frequently pointed out as a remarkable factor [2]. In addition, evidence recently published by the World Bank has shown that the primary difference between those who have escaped chronic poverty and those are still trapped in it is

not income, but access to essential services [3]. Transport is one of the main sectors; the Asian Development Bank (ADB) supports a reflection of the important role that transport plays in enabling economic development and poverty reduction [4, 5].

In the realm of transportation research, road infrastructure is frequently cited as a critical catalyst for regional social transformation and economic growth; it can generate payoffs for local development [6, 7]. However, how the payoffs come into effect remains uncertain. Polzin categorized the impacts of road infrastructure on economy development into three types: direct, indirect, and secondary [8]. The direct impacts are those related to the improved service and accessibility; the indirect impacts are those related to mediating community responses and policy change; the secondary impacts are those related to social perception and individual behavioral changes. In this context, it is

worthwhile to examine the pathways for the influence of the road infrastructure on the local economy and poor reduction using quantitative measurements.

As a multivariate statistical technique, structural equation modeling (SEM) can discover the direct or indirect relationships between exploratory variables and a dependent variable and then visualize the causal influencing pathways and mediating effect [9, 10]. Previous pilot studies have indicated that SEM is suitable for social and economic studies, and it can deal with the problem of causality between public capital and output. However, rarely have studies applied SEM to investigate the relationships between the road infrastructure and economic development, as well as the transport poverty alleviation. The primary objective of this paper is to explore the relationships between the road infrastructure and regional economic development using SEM. In particular, analysis is conducted in the concentrated contiguous destitute areas of Yunnan in southwestern inland China.

The concentrated contiguous destitute areas of Yunnan located in southwestern China are shown in Figure 1. Among the 14 concentrated contiguous destitute areas in China, there are four in Yunnan, which are composed of 91 cities/counties. These regions, respectively, account for 65.89% and 12.50% of the total number of administrative units at the county level and the total number of contiguous areas in China.

The concentrated contiguous destitute areas of Yunnan are among the most underdeveloped hilly regions in China. Their socioeconomic conditions and road infrastructure construction are significantly lower than the national average. This region provides useful cases to study the pathway for the influence of the road infrastructure on the local economy among poverty-stricken areas with development.

Under these circumstances, this study aims to provide a comprehensive empirical evaluation of the impact that transportation development has on economic growth and poverty reduction, which can assist the planning of traffic poverty alleviation and rural revitalization in the contiguous poverty-stricken areas of Yunnan (in China). This paper differs from existing research in several aspects. First, an overview of the interactive mechanism and processes has been offered by which road infrastructure investment influences poverty reduction and the characteristics of poverty space and spatial coupling result of road infrastructure have been systematically obtained. Second, a structural equation model (SEM) has been built, which comprehensively considers the mutual relationship between transportation investment and poverty reduction; meanwhile, social capital, material capital, and geographical capital have been added as endogenous variables in the model system. Third, the model system has been formulated with variables that reflect transportation input in adjacent geographical units to consider spatial spillover effects. Fourth, empirical analysis at regional level of the concentrated poverty-stricken areas in China has been conducted. The poverty alleviation path that has been proposed aims to catalyze actions to reduce the

transport-related exclusion in poverty-stricken areas caused by the lack of access to basic facilities (e.g., health, education, financial, and ecological facilities).

The remainder of this paper is structured as follows: Section 2 theorizes about the transport-region economic relationship. Then, the data sources and types are illustrated in Section 3, and the evaluation methods between road infrastructure and poverty rate are also applied. Section 4 mainly discusses the empirical results of research. Finally, this paper ends with some conclusions and discussion in Section 5.

2. Theorizing the Transport-Region Economic Relationship

2.1. Literature Review. Previous studies linking the local economy to road infrastructure can be traced back to the last century. The potential contributions of the transportation sector to poverty reduction have been investigated in several countries and institutions since the late 1960s [11–20].

In recent years, the conceptualization and measurement of transport disadvantages have garnered even more attention, particularly from academics and decision-makers of the developed countries, for being considered as a key driver of social inclusion and social justice [21–26]. This phenomenon has been illustrated by a number of studies pointing out that accessibility constraints tend to deepen sociospatial inequalities leading to multidimensional deprivations and, eventually, poverty traps [19, 27]. In this sense, accessibility, as the ultimate goal of most transportation, has been also proposed to be understood and planned as a fundamental human capability since it plays a central role in enabling people to meet their needs and promote healthy human flourishing [28–30]. Moreover, in spite of the increasing body of research dedicated to evaluating access to house facilities and healthcare services in rural China or low and middle income countries [31, 32], only few notable exceptions have been dedicated to quantitative evaluation of the overall accessibility poverty in such context [33–35].

Existing literature attempts to reveal the transport economic mechanisms using an econometric approach. These researches demonstrated the economic impact of transportation infrastructure investment through three pathways: (1) enhancing overall production productivity [36, 37], (2) accelerating technological spillovers across economic units [38, 39], and (3) reducing trade costs and enlarging sale spatial scope [40, 41].

Another branch of literature employs the classical statistical method to quantify the association between transportation infrastructure and the regional economy. An empirical analysis [42] showed that the impact of highway construction on population growth was weak in rural areas and strong in suburban areas. Guo proved that highway development, railway development, and railway investment all contributed positively to economic growth [43]. Iacono and Levinson pointed out that local road infrastructure and employment have no significant associations [7]. Yu found that road infrastructure improvements alone were not sufficient to promote economic growth at the national and

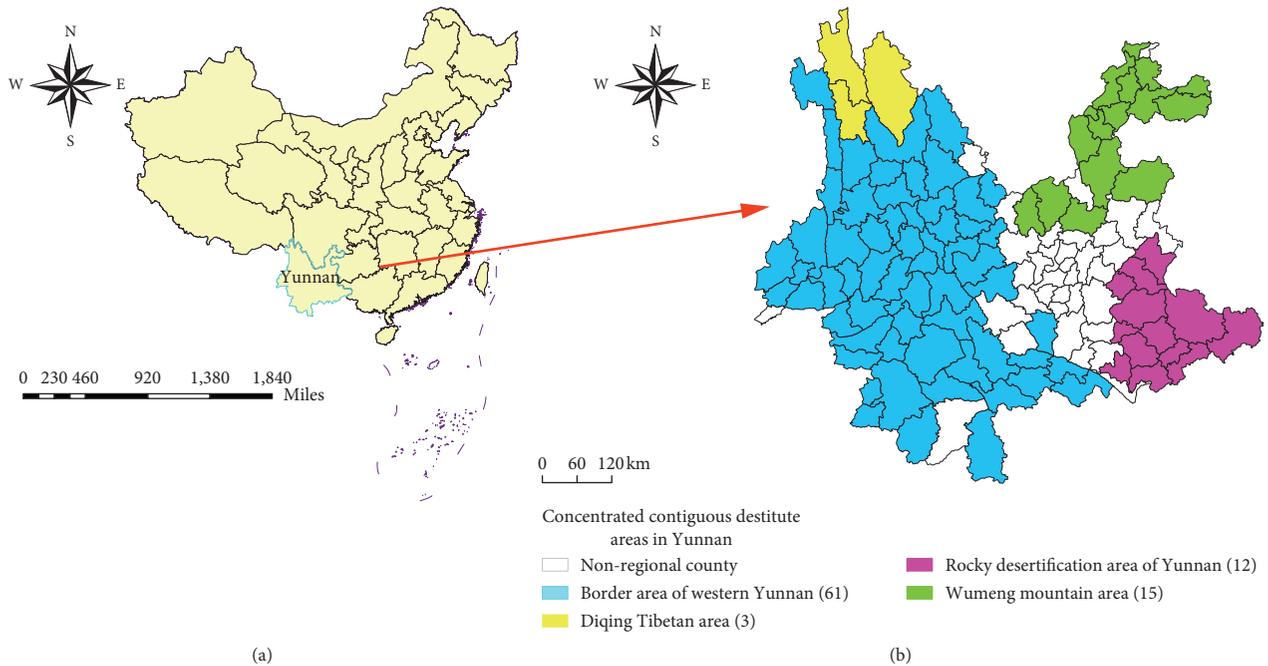


FIGURE 1: Location of the concentrated contiguous destitute areas of Yunnan, China.

regional levels in China [44]. Most of the above reviewed studies were case based and only show a certain specific pathway that explains the transport-region economic relationship.

These studies provide critical references for theorizing the transport-region economic relationship. Nevertheless, the studies on this subject are not comprehensive enough in geographical terms and have not covered most of the regions in developing countries where poverty is widespread [36, 45], especially in the contiguous poverty-stricken areas. The pathways for the influence of the road infrastructure on the local economy should be very complex. Poverty-stricken areas should be identified in order to compare the existing results of studies in developed regions. However, few efforts have focused on these areas and aspects. Additionally, no specific conceptual framework has been proposed to demonstrate the transport-region economic relationship with regard to road infrastructure construction.

2.2. Theoretical Framework. A growing body of empirical literature indicates that road infrastructure plays an important role in regional economic development, and it can generate payoffs for local development. However, there is uncertainty as to how the payoffs come into effect. Perfect road transportation service would positively increase the employment scale and income of poverty-stricken areas, influence the spatial location and layout of the market, and realize the effect of spatial agglomeration, while poor transportation infrastructure service may cause issues within the economic and social welfare system. The effects can be divided into two aspects: one is direct investment drive, and the other is

indirect economic spillover. Figure 2 offers a view of the mechanism and processes by which road infrastructure influences economic development and alleviates poverty [46].

On one hand, improving road transportation investment and service can directly reduce the production cost and improve the productivity of relevant industries in poor areas. It is also known as “cost saving effect,” which promotes total factors productivity growth (TFP) and the rate of economic growth in the poor areas. At the same time, road infrastructure investment can significantly reduce transport and travel costs, improve the accessibility and convenience of poor areas, and bring about multiplier effect of economic production activities.

On the other hand, the indirect effects of road infrastructure on economic growth and poverty alleviation can be categorized into three aspects: spatial spillover effect, spatial agglomeration and technical diffusion effect, and attraction effect. Road infrastructure has the characteristics of network and externality. Positive spatial spillovers take place when connectivity and accessibility in the surrounding areas are improved, those would then lead to the immigration of knowledge, technology, and resources to surrounding areas and strengthen attraction in the poor regions. In addition, the attraction effect would promote connectivity and improve resource allocation. The three effects and mechanisms influence the evolution and adjustment of regional spatial structure, thus promoting the development of regional economic. The “trickle-down effect” of economic growth can indirectly improve the quality of social services, such as medical care, education, and banking in poor areas and make it easier for the poor to enjoy facilities and services, so as to reduce poverty.

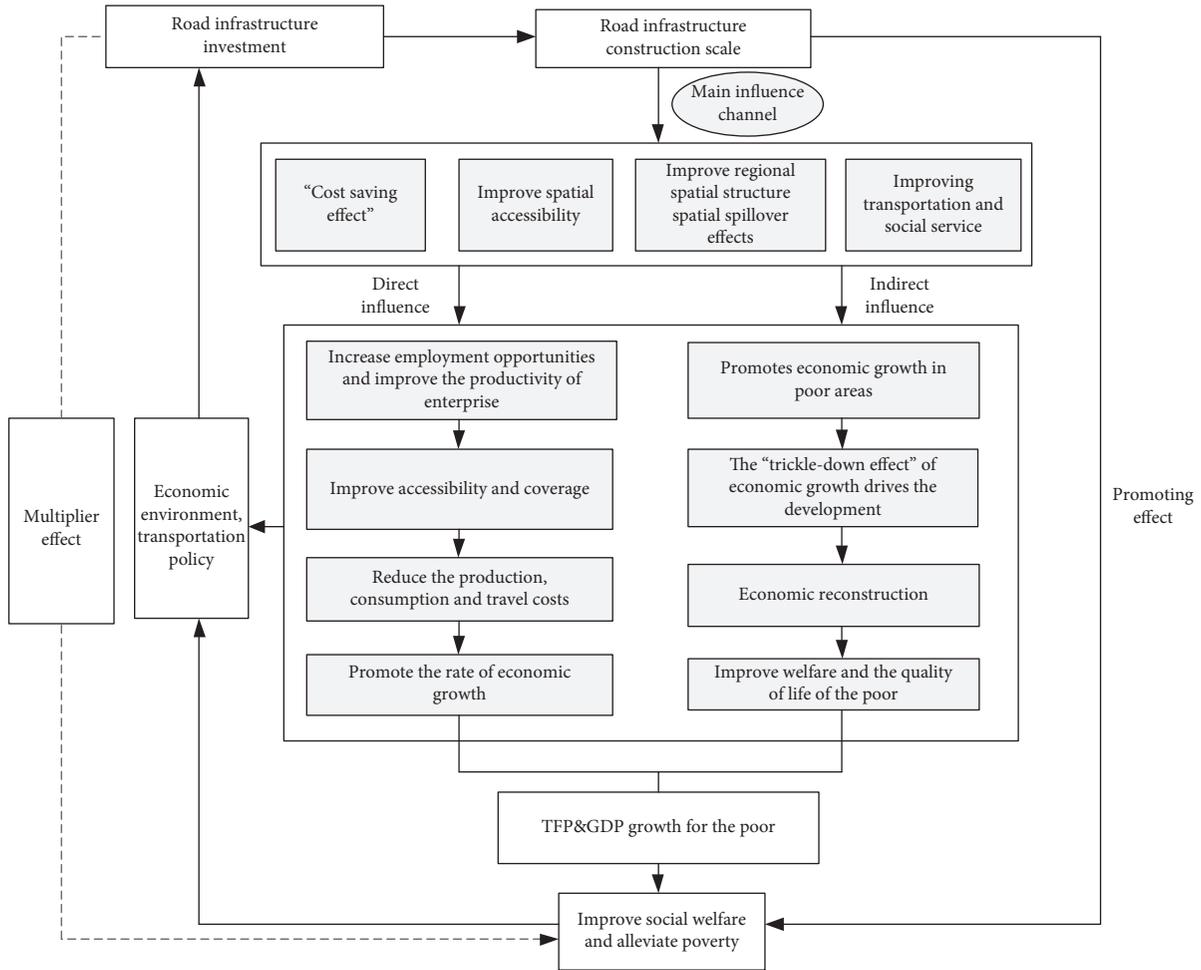


FIGURE 2: Theoretical framework for the influencing pathway between road infrastructure and local economy.

3. Materials and Methods

3.1. Data Sources. This paper takes 91 cities/counties in the concentrated contiguous destitute areas of Yunnan province as the research object. The research data are mainly composed of the basic geographic data and the social public service guarantee data as shown in Table 1.

3.2. Statistical Analysis and Modeling

3.2.1. Road Infrastructure Assessment Model. Before turning to theoretical and empirical investigation, we made some descriptive statistics on the road infrastructure and poverty incidence in the study area.

Yunnan province, as an underdeveloped region in the west, is located on the Yunnan–Guizhou plateau with complex terrain. Compared with other modes of transportation, the highway network has a large scale and is the leading mode of the comprehensive transportation system of the whole province. In this paper, the configuration of road infrastructure is used to represent the situation of road infrastructure in the whole province. Considering the practicability of the data, four indexes of highway mileage, highway proportion, and the number of passenger

stations above grade 2 are selected to construct the configuration status of road infrastructure at county level. In order to avoid the influence of subjective factors, the evaluation model of road infrastructure based on entropy weight method is constructed. The model expression is as follows:

$$z_{ij} = \frac{x_{ij}}{\sum_{i=1}^n x_{ij}},$$

$$e_j = -\frac{1}{\ln m} \sum_{i=1}^m z_{ij} \ln z_{ij},$$

$$d_j = 1 - e_j, \quad (1)$$

$$w_j = \frac{d_j}{\sum_{i=1}^n d_j},$$

$$\text{HIC}_i = \sum_{j=1}^n w_j z_{ij}.$$

In this formula, x_{ij} is the value of the j -th index of the i -th research unit; z_{ij} is the normalized value of the j -th index of the i -th research unit; m indicates the total number of research units; e_j is the entropy value of index j ; d_j is the entropy redundancy of index j ; w_j indicates the weight of index j ; n is

TABLE 1: Data sources.

Dimension	Representative variables	Variable description	Data sources	Data source type
Basic geographic data	Vectorization of highway data	Vectorization of highway	Highway atlas 2015 (People's communication press)	Analytical data
	Per capita GDP	Per capita GDP	Yunnan Statistical Yearbook ¹	
	Annual net income per capita	The initial distribution and redistribution of income of urban households	China Statistical Yearbook For Regional Economy	
	Public budget revenue	Financial income for safeguarding and improving people's livelihood	China City Statistical Yearbook	
Socioeconomic factors	Total power of agricultural machinery	Reflecting the status of agricultural machinery owned by rural residents	Compilation of Transportation Statistics in Yunnan Province ²	Statistical data
	Fixed telephone year-end user	Telephone penetration directly reflects the poverty level of regional residents	Statistical Bulletin on National Economy and Social Development in Yunnan Province	
	Urbanization rate	The ratio of the permanent population of the town to the total resident population of the district		
Social security	Fixed asset investment	Reproduction of fixed assets	Annual Statistical Bulletin of Counties and Districts	
	Number of social welfare adoption units	Reflecting the social welfare facilities and basic security status of the region		
	Per capita housing construction area	Average residential building area per person based on resident population		
Material capital	Aging proportion	The proportion of the elderly population to the total population		
	Rural road investment	Reflecting the state's investment in rural infrastructure		
Transportation facilities	County road pavement rate	Reflecting the quality and popularity of transportation infrastructure		
	Road network density			
Geographic capital	The population density	Population density is the number of people living on a unit of land		
	Grain planting area	Cultivated land is the most important material livelihood capital, and grain yield usually highly correlates with poverty		
	Annual average precipitation	Rainfall reflects regional ecological conditions		

¹Yunnan Statistical Yearbook (1988-2017), Yunnan Provincial Bureau of Statistics (2000-2017), Yunnan Provincial. ²Yunnan Province Traffic Statistics Compilation (2000-2017), Yunnan Provincial Department of Transportation (2000-2017).

the total number of evaluation indicators; and HIC_i is the road infrastructure grade score of the research unit i .

3.2.2. Coupling Harmonious Degree Model. In order to obtain the level of coordination between road infrastructure and poverty rate at the county scale, a coupling coordination degree model was constructed. The model expression is as follows:

$$W_i = 2 \times \left[\frac{K_i \times H_i}{(K_i + H_i)^2} \right]^{(1/2)}, \quad (2)$$

$$\begin{aligned} X_i &= \sqrt{W_i \times Q_i}, \\ Q_i &= \alpha K_i + \beta H_i. \end{aligned} \quad (3)$$

In this formula, W_i denotes the coupling degree of the area and county i ; K_i and H_i denote the road

infrastructure grade score and poverty incidence rate of county i ; X_i indicates the coupling coordination degree of the area and county i ; Q_i indicates the comprehensive coordination index of the score of road infrastructure grade and poverty incidence in the area and county i ; and α , β are the undetermined coefficients, which are generally 0.5.

3.2.3. Structural Equation Model. The economic impact of transportation infrastructure investment is the most widely discussed issue, and various methodologies have been applied to address this problem. The most common approaches are the production function model and the cost function approach. [47–49]. Although they are widely used, there are still some problems. The production function model does not account for simultaneity or any noncontemporaneous effects among the different variables. Although the cost

function approach is able to show whether transportation investment can contribute to economic development and how this effect is realized, it also has its own shortcomings of spurious correlation, nonstationary, and noncointegration [46]. Compared with the above-mentioned approaches, structural equation model (SEM) is flexible and practical; it can be preperceived by correspondence canonical analysis. Therefore, SEM is employed to investigate the transport-region economic relationship, as well as the mediating factors. We perform the F test for variance homogeneity, the Shapiro–Wilk test for normality, and the standard deviation model for standardization. The maximum likelihood was employed to establish the SEMs for the concentrated contiguous destitute areas of Yunnan. To evaluate the model performance, we refer to several well established indicators, including the chi-square (χ^2) test, the goodness-of-fit index (GFI), the comparative fit index (CFI), the root mean squared error of approximation (RMSEA), and the adjusted goodness-of-fit index (AGFI). Model validity is evaluated by the critical ratio (CR) and item reliability (R^2). Acceptable values for the two indicators are recommended as $|CR| > 2.0$ and $R^2 > 0.5$. Relationships among different variables are interpreted based on the standardized coefficients [9].

The initial structural equation model contains five latent variables and 30 observed variables; according to the test results, the structural equation model established in this paper is overidentified. The revised model includes 14 indicators reflecting the county's natural geographical conditions, resource endowments, traffic location, education level of residents, welfare protection, and social and economic development level. The model introduced potential variables on the basis of considering the path relationship between exogenous variables and endogenous variables.

$$y = By + \Gamma x + \zeta, \quad (4)$$

where y is the exogenous latent variables, represented by a vector composed of endogenous indicators; x is the endogenous latent variables, represented by a vector composed of exogenous indicators; B is the coefficient of interaction between endogenous latent variables; Γ is the effect coefficient of exogenous latent variables on endogenous latent variables (path coefficient); and ζ is the residual vector of the structural equation, reflecting the unexplained part of y in the equation.

The road infrastructure is based on structural equation model to construct poverty reduction path and the strength of research methods, mainly through path graph and effect value to analyze road infrastructure construction investment and how it affects the economic growth and poverty reduction, as well as how road infrastructure indirectly contributes to poverty reduction through other industries and capital, to characterize the spatial spillover effects of the road infrastructure and the effectiveness of comprehensive poverty alleviation.

4. Results

4.1. Analysis of Spatial Characteristics of Road Infrastructure and Poverty Incidence. Based on the data of highway

infrastructure and poor population, formula (1) and poverty rate formula are used to calculate the road infrastructure grade score and poverty incidence in the research area, and ArcGIS spatial analysis technology is used to describe its spatial characteristics. The detailed analysis results are presented in Figures 3 and 4.

- (1) Unbalanced distribution and unreasonable proportional structure of road network in Yunnan province were found. The rural road coverage rate is obviously insufficient, resulting in the low level of the overall road network.
- (2) Yuanjiang valley and the south section of Yunling mountain, taken as the boundary, present a high-low distribution “transition zone” of road infrastructure from Deqin County to Hekou County, with east Yunnan and central Yunnan high-value areas in the east, low-value areas in the border area of Western Yunnan, and the high-value area and low-value area showing the characteristics of strong spatial agglomeration.
- (3) The poverty in the study area presents a strong spatial heterogeneity. The areas with high poverty rate are mainly concentrated in the Diqing Tibetan area and the Wumeng Mountain area, forming “double cores” of different sizes.

4.2. Spatial Coupling Results of Road Infrastructure and Poverty Rates. On the basis of obtaining the characteristics of road infrastructure and poverty, formulas (2) and (3) are used to calculate the coupling and coordination value of road infrastructure and poverty rate in the district counties, and the coupling and coordination value is divided into five spatial relations according to the calculation results, as shown in Figure 5.

- (1) About 70% of the district counties' road infrastructure and poverty rate are in a state of spatial coupling imbalance. Among them, as one of the “three districts and three states” in the deep poverty areas, Nujiang belongs to a typical type of maladjustment and common loss. Influenced by terrain, geological conditions, resource endowment, and other factors, the lag of road infrastructure and deep poverty are intertwined for a long time.
- (2) The coordinated synchronous type is mainly distributed along the transportation network. For example, the continuous promotion of the construction of Kunming–Qiaojia expressway and Panzhihua–Zhaotong–Bijie–Zunyi railway will speed up the gradual improvement of the comprehensive transportation system of Qiaojia and Dagan Counties, and the steady improvement of economic development. The completion and opening of the high-speed railway between Yunnan and Guangxi have driven the rapid development of tourism, characteristic agriculture, and service industry in Maitreya, and the number of employees has increased significantly.

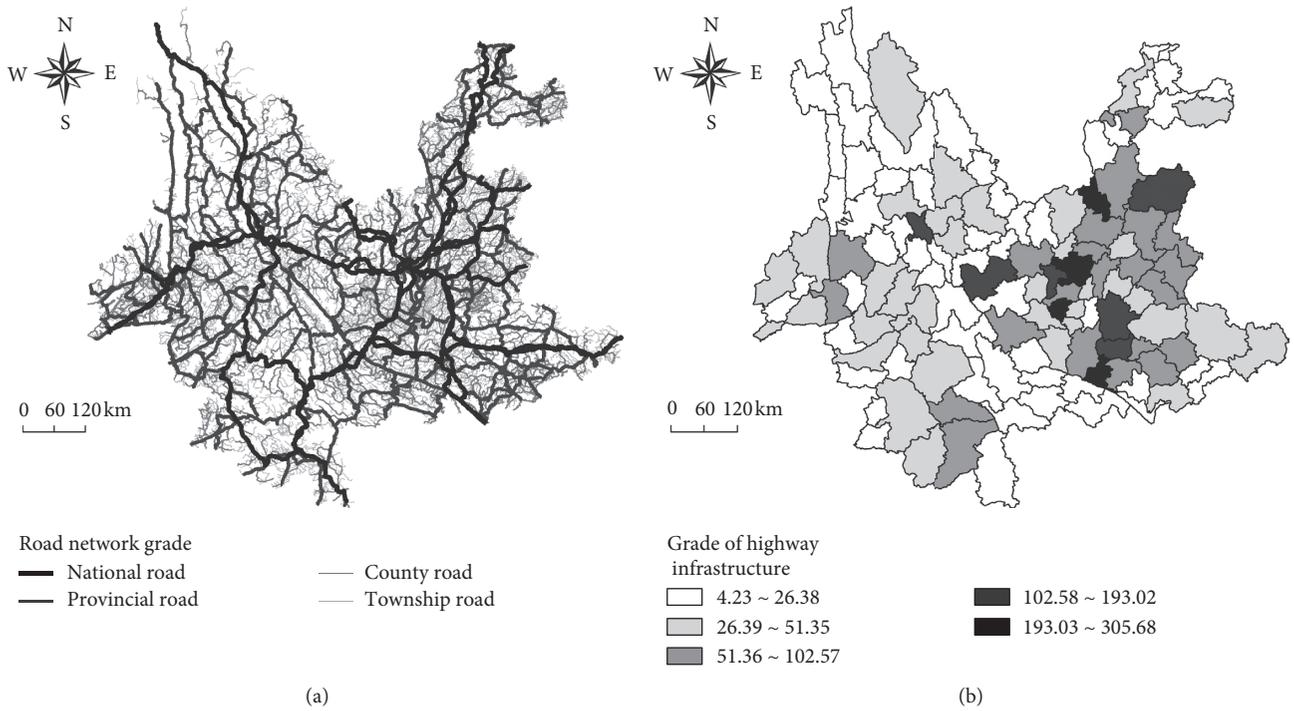


FIGURE 3: Spatial distribution of road infrastructure network and hierarchy. (a) Road network grade. (b) Road infrastructure assessment.

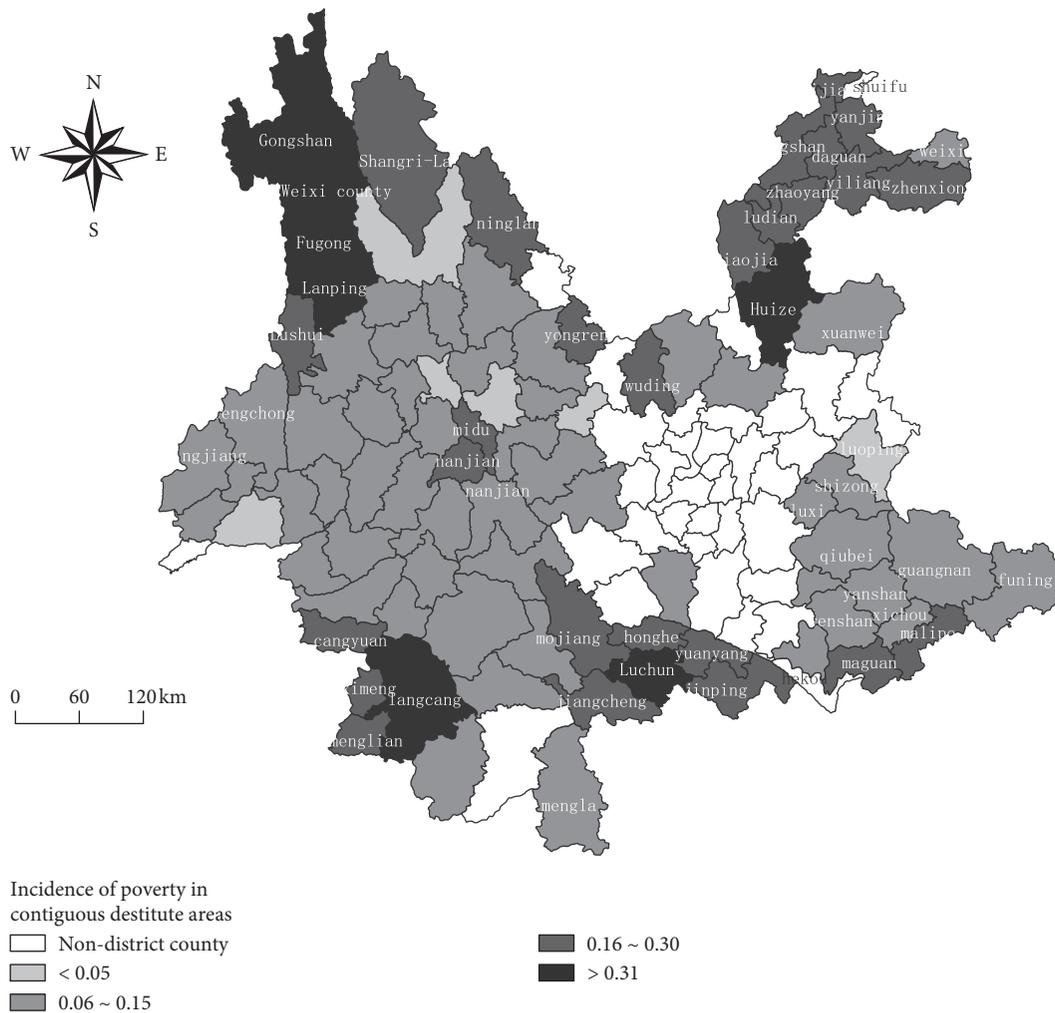


FIGURE 4: Spatial distribution of poverty rate.

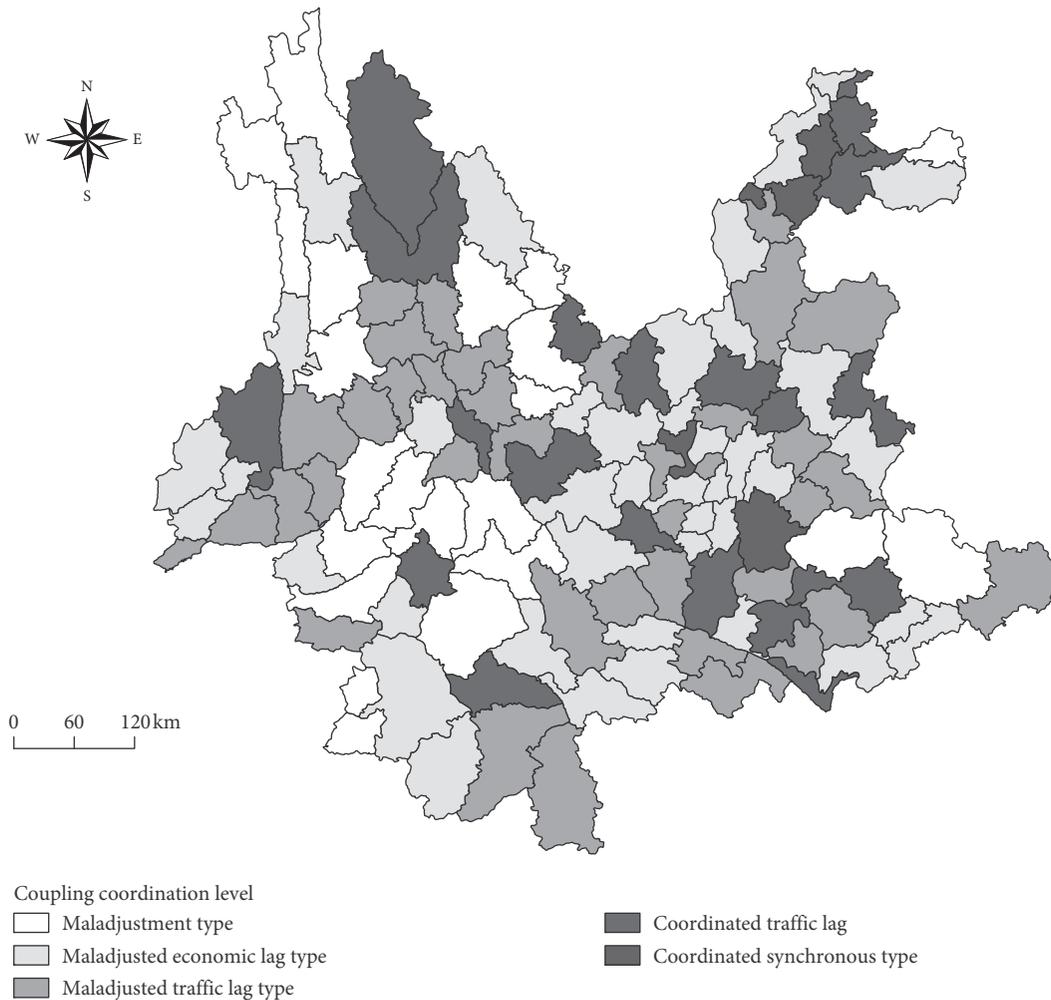


FIGURE 5: Spatial pattern of coupling coordination degree.

4.3. The Path and Intensity of Poverty Reduction on Road Infrastructure. On the basis of determining the coupling and coordination relationship between road infrastructure and poverty rate, the effect of poverty reduction becomes the focus of attention. Furthermore, structural equation model was used to quantify the path and intensity of action of road infrastructure investment and construction on poverty reduction.

The revised model overall fitness test and the optimal model parameter estimation results are shown in Tables 2 and 3. The analysis results show that the test results are generally matched, and the path coefficients in the model basically reach the significance of 1% level. The following path coefficients are acceptable, and the model variance estimates are all positive and consistent with the level of significance.

In the structural equation model, the path coefficient value reflects the impact of different variables such as road infrastructure, social capital, and geographical capital on poverty reduction. Investment and construction of road infrastructure stimulate the economy to achieve the ultimate goal of reducing poverty through direct or indirect diversification of routes, as shown in Figure 6.

- (1) In terms of the direct poverty reduction effect, the road infrastructure investment and construction can directly affect the poverty reduction, with a path coefficient of 0.105, which is very significant. However, the direct effect is far lower than the indirect poverty reduction effect (0.830) brought by the road infrastructure investment and construction, which affects geographical location, fixed asset investment, secondary and tertiary industries development, and urbanization. This shows that the contribution of transport infrastructure investment and construction to poverty reduction is more indirect in the form of spatial spillover, network attributes, and externality of road infrastructure construction, which play an important role in economic development and poverty reduction. The enlargement of road networks would definitely accelerate capital and resource flow, as well as human movement. Consequently, the local interactions with outside economy are increased. Such interactions are considered critical drivers for economic growth in less developed areas. In particular, inputs from other sectors can be created and increased by road network

TABLE 2: Evaluation results of the modified model.

Statistical test	X^2	df	X^2/df	RMSEA	CFI	NFI	GFI	IFI	AGFI
Fitness threshold	—	—	1 < NC < 3, good 3 < NC < 5, not too bad	RMSEA < 0.5, good 0.5 < NC < 0.8, not too bad	>0.9	>0.9	>0.9	>0.9	>0.9
Inspection result	212.584	75	2.826	0.484	0.961	0.934	0.968	0.985	0.944
Adaptation judgment	—	—	Good	Good	Perfect	Perfect	Perfect	Perfect	Perfect

TABLE 3: Estimation results of the variable coefficient and significance test.

Acting path	Estimate	SE	CR	P	Label	Standardized estimates
Material capital < --- road infrastructure	0.470	0.270	2.742	0.002	par_21	0.323
Geographical capital < --- road infrastructure	0.020	0.002	8.843	***	par_29	0.669
Social capital < --- material capital	4.697	2.485	1.980	0.039	par_13	0.458
Social capital < --- geographical capital	385.159	64.215	5.998	***	par_14	0.757
Traffic dominance < --- road infrastructure	1.000					0.804
Highway network density < --- road infrastructure	0.146	0.030	4.818	***	par_1	0.572
Poverty reduction effect < --- material capital	3599.722	3506.741	3.027	***	par_18	0.263
Poverty reduction effect < --- social capital	1509.292	576.523	2.618	**	par_19	1.132
Poverty reduction effect < --- geographical capital	7535.539	224994.298	3.033	***	par_25	0.011
Total power of agricultural machinery < --- social capital	1.000					0.702
Revenue from the public budget < --- highway network density	2291.362	534.740	4.285	***	par_17	0.166
Minority share < --- transport advantage	1414.846	263.234	5.375	***	par_27	0.284
Rural road investment < --- road infrastructure	0.053	0.017	3.201	***	par_2	0.230
Per capita housing construction area < --- material capital	1.000					0.163
Number of social welfare adoption units < --- material capital	0.755	0.451	2.675	**	par_3	0.213
The proportion of aging < --- material capital	0.006	0.003	2.986	***	par_4	0.412
Grain production < --- geographical capital	1558.083	1032.655	2.809	***	par_5	0.131
Urbanization rate < --- poverty reduction effect	0.007	0.001	7.897	***	par_6	0.615
Fixed-line users at the end of the year < --- social capital	699.746	114.571	6.108	***	par_7	0.401
Per capita GDP < --- poverty reduction effect	1.000					0.702
Revenue from the public budget < --- social capital	0.000	0.000	20.600	***	par_9	1.109
Fixed assets investment < --- social capital	8.685	0.681	12.760	***	par_20	0.959
Population density < --- geographical capital	1.000					0.726
The proportion of aging < --- total power of agricultural machinery	0.000	0.000	6.899	***	par_22	0.449
Per capita housing construction area < --- proportion of ethnic minorities	0.001	0.000	11.120	***	par_28	0.627

“<---” indicates the orientation in which the utility occurred; ** $P < 0.01$, *** $P < 0.001$.

construction, and the multiplier economic effect is subsequently stimulated. This finding suggests that the realization of the effect of road infrastructure on economic growth needs the synergy of institutional environment improvement, human capital improvement, science and education technology level improvement, and other factors. When analyzing the causes of economic growth, multidimensional factors need to be taken into account in order to improve the social welfare and reduce transport poverty in poverty-stricken areas. This discovery is in line with the past literature reporting that the spatial structure evolution was closely linked with road infrastructure construction [50, 51].

- (2) In terms of the indirect poverty reduction effect, there is a significant difference in the path and degree of the road infrastructure to promote economic growth and ultimately reduce poverty. This paper mainly works through five poverty reduction path

modes of road infrastructure. Among them, “ road infrastructure \rightarrow social capital \rightarrow poverty reduction effect” has the highest path coefficient (0.740), and the contribution of fixed asset investment and public budget income to social capital is 0.959 and 1.109, respectively, which are higher than other poverty reduction factors.

- (3) Road infrastructure investment and construction can guide economic development and reduce poverty by acting on geographic capital, material capital and social capital. The overall action coefficient is 0.740, which is higher than the poverty reduction effect of the two paths of “road infrastructure \rightarrow geographic capital/material capital \rightarrow poverty reduction effect”. The path coefficient of “road infrastructure \rightarrow geographical capital \rightarrow social capital \rightarrow poverty reduction effect” is 0.573, which is higher than that of “road infrastructure \rightarrow material capital \rightarrow social capital \rightarrow poverty reduction effect” (0.167).

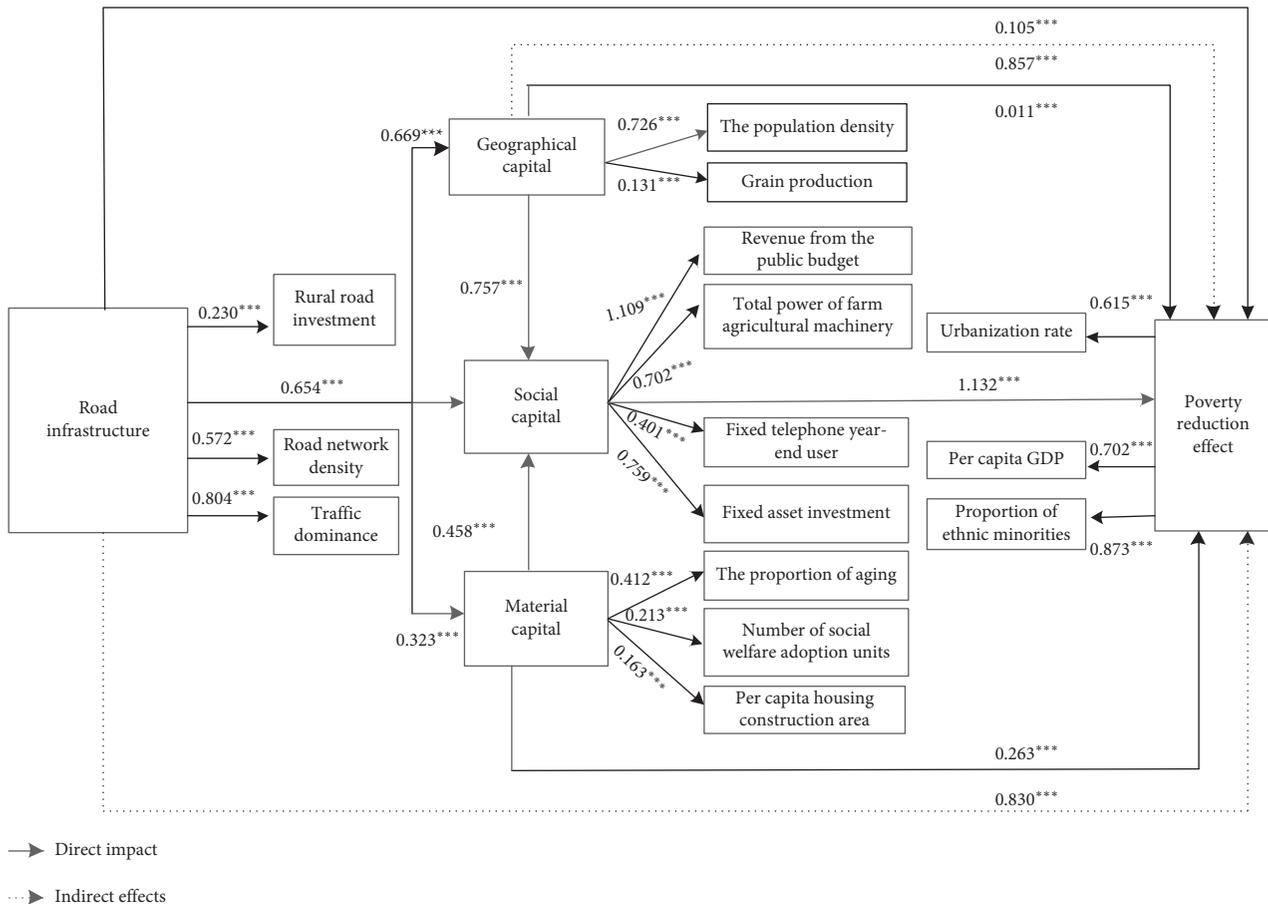


FIGURE 6: Estimation results of the SEM for poverty alleviation path of road infrastructure.

- (4) Either the investment and construction of transportation infrastructure itself or the associated capital and industrial development brought by it are obviously conducive to economic growth and employment of the poor. Taking the construction of highway transportation investment and construction as an example, in the link of road production and construction, highway transportation investment and construction can attract a large amount of labor to increase nonagricultural employment opportunities, reduce transportation costs, and improve production efficiency. In the link of traffic operation, highway traffic investment and construction can promote the location choice, productivity distribution, and production factor agglomeration of enterprises.

5. Conclusion and Discussion

5.1. Conclusion. In this paper, the evaluation model of transportation infrastructure based on entropy weight method and a coupling coordination degree model are established, obtaining the spatial characteristics and spatial coupling results of road infrastructure and poverty incidence. On that basis, a structural equation model has been established to describe the relationships between the variables, and the relationship between transportation

investment and regional economic growth is estimated. Based on the results of empirical study, the following key conclusions are drawn.

- (1) The structural equation model confirms the significant effect of road infrastructure investment and construction on economic growth and poverty reduction, but the path and degree of poverty reduction are quite different. The direct effect of road infrastructure investment and construction on poverty reduction is far less than the indirect effect, and the diversification path is produced indirectly through the form of spatial spillover. Among the five path models of poverty reduction effects on road infrastructure, “road infrastructure → social capital → poverty reduction effect” has the highest path coefficient of poverty reduction, and the effect of poverty reduction is the best.
- (2) The contribution rate of the number of passenger stations above grade 2 and county road pavement rate is higher than those of other traffic indicators, which is the most important poverty reduction factor in the study area.
- (3) About 70% of the district counties’ road infrastructure and poverty rate are in a state of spatial coupling imbalance. The coordinated synchronous

type is mainly distributed along the transportation network.

The research results can provide theoretical and practical basis for the formulation of transportation poverty alleviation strategy, so as to effectively play the leading and supporting role of transportation infrastructure in poverty alleviation and rural revitalization. In order to more comprehensively analyze the impact of transportation supply on economic growth and poverty reduction, based on the theory of spatial equity and the principle of regional deprivation compensation, we put forward the poverty alleviation and optimization strategy of traffic resource allocation in the concentrated contiguous destitute areas from the perspective of spatial equity:

- (1) Speeding up the building of a transportation network that connects the poverty-stricken areas with the outside world and the inside world and connects the villages and townships
- (2) Innovating ways of providing transportation to help the poor and advancing a new comprehensive approach of transportation poverty alleviation
- (3) Developing public-private partnerships (PPP) in various forms and innovating investment and financing mechanisms

Considering this strategic decision-making in the statistical model could produce interesting and useful policy insights.

5.2. Discussion. Transportation infrastructure has complex interactions with regional economic systems. Prior studies indicate that impacts of transportation infrastructure are more pronounced in developing countries, as the prevalence of infrastructure is lower in these countries [52]. This paper builds several models to uncover the contributing factors in mediating the relationships between the road infrastructure and local economy in the concentrated contiguous destitute areas of Yunnan. We found that the established models are efficient in revealing the relationship between the road infrastructure and the less developed places' economy. Previous studies advocate road infrastructure as a primary economic catalyst in less developed areas, as it can increase the accessibility to market, eliminate constraints to social services, and provide employment [6, 7]. The results for the concentrated contiguous destitute areas of Yunnan are in accordance with earlier findings.

This paper demonstrates that SEM is efficient in our case. However, SEM is not always strong in proving causality. Regional and local policies regarding road infrastructure investment promoting economic growth differ significantly across various regions in different countries; when applying the demonstrated methodology to other areas worldwide, it requires caution and further verification. Though our study advances the understanding of the relationships between the road infrastructure and regional economic, it still has certain shortcomings. First, all the indicators of the article are chosen based on empirical literature review and data

availability; subjectivity is unavoidably associated with the selection methods by which the exploratory variables can be selected more scientifically. Second, the SEMs are established by using the maximum likelihood approach in this study. However, whether or not this approach is a methodological advantage remains unproven. Third, this paper examines the concentrated contiguous destitute area at the provincial level; to deepen the understanding of the relationship between the road infrastructure and local economy, future studies should investigate and compare different regions with different levels of development. Fourth, road infrastructure is not the only type of road infrastructure. Since the highway network has a large scale and is the leading mode of the comprehensive transportation system of the Yunnan province, our study does not consider railways and high-speed rails. Some studies have evidenced the effect of high-speed rails on the economic characteristics; consequently, the exclusion of railways may overestimate the empirical findings in this study. Further studies should control the railways and high-speed rails, to isolate the individual effect of road infrastructure on the urban economy.

Data Availability

The data that used to support the findings of this study are currently under embargo while the research findings are commercialized. Requests for data, 12 months after publication of this article, will be considered by the corresponding author.

Disclosure

The funders had no role in the design of the study or in the collection and interpretation of the data.

Conflicts of Interest

The authors declare no conflicts of interest.

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