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Research on the Interactive Impact of Transportation Systems on Socio-Economic Development

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Abstract: This paper aims to explore the interactive impact between transportation systems and socio-economic development, employing Structural Equation Modeling (SEM) to analyze data from 31 provincial-level administrative regions in China from 2013 to 2022. It comprehensively considers key indicators from the economic, social, and transportation sectors. The paper constructs a model encompassing 5 latent variables and 15 observed variables. Through in-depth analysis, it reveals the promoting role of transportation systems on economic growth and social development, as well as the demand for transportation system construction and optimization driven by socio-economic development levels. The results indicate that an efficient transportation system can not only directly drive economic growth but also indirectly promote social development by improving social welfare and enhancing quality of life. This paper provides new insights into understanding the complex relationship between transportation systems and socio-economic development and holds significant implications for policymakers in optimizing transportation infrastructure to foster economic and social development.

Keywords: Transportation system; Socio-economic development; Structural equation modeling; Data analysis

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1. Introduction

The transportation system is an important infrastructure to promote the development of modern society and economy, and its efficient operation plays an indispensable role in promoting economic growth and social progress. In the context of globalization, an optimized transportation system can significantly accelerate the flow of goods and people, improve production efficiency, and promote regional economic integration, thus having a far-reaching impact on the improvement of people's living standards and social welfare. Currently, the research on domestic transportation systems mainly focuses on the coordinated development of air transport systems and the innovation of urban traffic management, focusing on the close interaction of transportation systems and economic and social development, as well as the impact of transportation system optimization on social welfare and quality of life. Han *et al.* pointed out that the coordinated development of the air transport system plays a key role in the economic and social development of cities, which emphasizes the close interaction between the transport system and the economic and social development [1]. Xu *et al.* proposed that the innovation of urban traffic management is crucial to addressing the current environmental challenges and promoting sustainable development [2]. By discussing the impact of the optimization and development of transportation systems on social welfare and quality of life, Fan *et al.* proposed the urban traffic management strategy for the era of digital intelligence [3].

At present, foreign regional transportation research mainly focuses on transportation integration, focusing on field investigation, and model analysis to improve connectivity and reduce transportation costs. Li *et al.* noted that regional transport integration promotes high-quality economic development by improving connectivity and reducing transport costs [4]. Hu *et al.* showed that intercity rail transit plays an important role in the economic integration of the Greater Bay Area [5]. The causal relationship between regional freight turnover and Gross Domestic Product (GDP) was highlighted by Ma *et al.* [6]. Zhang *et al.* found that transportation convenience is key to economic growth and transportation land is crucial [7]. Yang *et al.* pointed out that regional development is unbalanced by traffic heterogeneity, and the connection between regional transportation and urban economy is not clear [8]. Chen *et al.* emphasized the importance of transportation connectivity strategy to the economic growth of tourism and the improvement of transportation accessibility significantly affected regional economic growth, and different transportation modes were affected differently [9,10].

This paper analyzes the relationship between economic growth, social development, and transportation systems in 31 provincial administrative regions in China from 2013 to 2022. A comprehensive model of five potential variables including economic growth, social development, shipping system, high-speed railway system, and urban transportation system and its related 15 observed variables was constructed. Through the in-depth analysis of the model, this study reveals the complex interaction mechanism between the transportation system, social, and economic development and further verifies the importance of transportation system optimization for promoting all-round economic and social development.

Furthermore, this study focuses on the indirect effects of the optimization and development of transportation systems on social welfare and quality of life. The results show that an efficient transportation system not only directly promotes economic growth, but also indirectly promotes the overall development of society by improving social welfare and improving quality of life. Therefore, this paper provides an important scientific basis for policymakers in the planning and construction of transportation infrastructure, emphasizes the importance of sustainable development of transportation systems, and provides a new perspective for the overall economic and social progress.

2. Study hypotheses and model construction

2.1. Research hypothesis

In areas of research exploring the interactive impact between transport systems and socio-economic development, accurately identifying and understanding the complex interactions between these variables is critical to developing effective policies and optimizing transport infrastructure. This study uses the structural equation model (SEM) method to construct a theoretical framework to comprehensively analyze the interaction between economic growth, social development, and transportation systems. Based on this, this paper presents a series of research hypotheses aiming to explore the underlying causal relationships and interaction mechanisms. The specific model assumptions of this study are shown in **Table 1**.

Table 1. Table of assumptions of latent variables influencing relationships

Suppose the number	Study hypothesized relationships	Theory evidence
H1	There is a positive correlation between economic growth and the shipping system	The expansion and upgrading of the shipping system accelerated with the economy
H2	There is a positive correlation between the social development and the urban transportation system	With the improvement of social development, the urban transportation system will show higher efficiency and a wider service scope
H3	There is a positive correlation between the high-speed railway system and the economic growth	Economic growth and the expansion of the high-speed railway system show a synergistic increase
H4	There is a positive correlation between the shipping system and social development	The progress of the shipping system and the social and economic development show mutual promotion
H5	There is a positive correlation between the high-speed railway system and the social development	The level of social development is positively related to the expansion degree of the high-speed railway system
H6	There is a positive correlation between the urban transportation system and the economic growth	Economic growth and the expansion and optimization of the urban transportation system show a trend of synchronous improvement
H7	There is a positive correlation between the shipping system and the high-speed railway system	The expansion of the high-speed railway system and the progress of shipping system are mutually positive driving forces

In conclusion, this paper presents a theoretical model diagram of the interactive effects between the transportation system and socio-economic development, as shown in **Figure 1**.

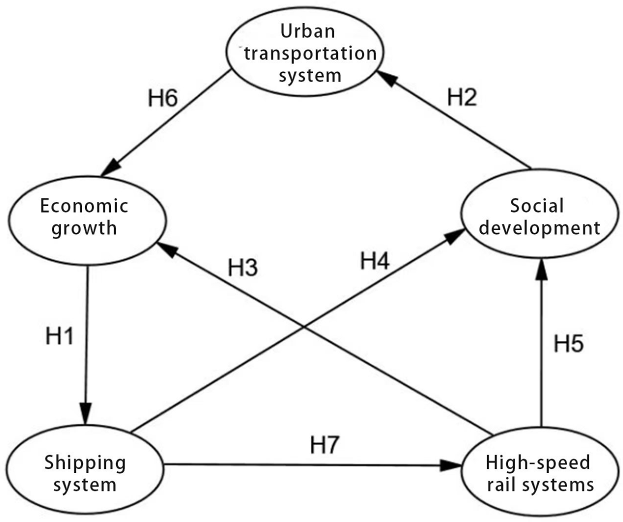

Figure 1. A theoretical model affecting the relationship between the latent variables

2.2. Model building

The structural equation model includes two components: the measurement model and the structural model [11]. The measurement model is designed to measure the latent variables, where dominant variables reflect the latent variables. Specifically, the measurement model can be expressed as the following equation: observed variable = factor load × latent variable + measurement error [12]. The available formula is expressed as follows:

$$\begin{cases} X = \Lambda_x \xi + \delta \\ Y = \Lambda_y \eta + \varepsilon \end{cases}$$

The structural model reveals the causal relationships and interactions between the variables. Specifically, the structural model can be expressed as the following equation: latent variable = path coefficient × latent variable + error term [13]. The available formula is expressed as follows:

$$\eta = \Lambda\eta + \Gamma\xi + \zeta$$

3. Data collection and analysis

3.1. Data collection

This paper aims to explore the interactive influence between the transport system, social, and economic development, especially in the context of 31 provincial administrative regions in China (excluding Hong Kong, Macao, and Taiwan). To achieve this goal, we collected time series data from 2013 to 2022, focusing on five aspects: economic growth, social development, shipping system, high-speed rail system, and urban transportation system. The data are mainly collected from the National Bureau of Statistics, China Railway Corporation, the Civil Aviation Administration of China, and other official statistical yearbooks. The latent and observed variables are shown in **Table 2**.

Table 2. The index system

Latent variable	Observable variable	Variable number	Observational variable definition
Economic growth	Per capita GDP	EG1	The ratio of the absolute GDP to the average population of the year
	Regional GDP	EG2	The sum of the final results of the production activities of all permanent units in a region within a certain period
	Value added	EG3	The final results of industrial production activities of industrial enterprises expressed in the form of currency during the reporting period
Social development	Per capita disposable income of all residents	SD1	The average income level that urban or regional residents can use for consumption or savings after deducting taxes
	Urban employment	SD2	Total number of people who have stable jobs in urban areas for a certain period
	Educational appropriations	SD3	Total financial resources allocated and used for educational services and activities over a certain period
Shipping system	Employment in the air transport industry	SS3	Total number of regular and temporary employees engaged in the air transport industry for a certain period
	Total length of air mail road	SS4	The total length of all air mail transmission routes in a country or region
High-speed railway system	Railway mileage	HR1	The total mileage of trains in the network, including the length of all tracks in operation
	Railway passenger traffic volume	HR2	Passenger volume of railway brigade refers to the number of passengers transported by railway buses within a certain period
	The volume of railway freight	HR3	Railway freight volume refers to the amount of goods transported by railway freight cars within a certain period
Urban transportation system	Number of public transport vehicles operated	CT1	The number of public transport vehicles operated includes the number of bus and tram operations and the number of rail transit operations
	Public transport passenger volume	CT2	The total amount of public transport passenger traffic includes the passenger volume of public bus, tram, and rail transit passenger traffic
	The number of traffic accidents that have occurred	CT3	The number of traffic accidents refers to the total number of traffic accidents recorded in a certain area within a certain period
	Number of deaths in traffic accidents	CT4	The number of deaths in traffic accidents refers to the total number of dead individuals directly caused by traffic accidents within a certain period

Based on model assumptions and variables analysis, the structural equation model for the interaction of the transportation system and socio-economic development is shown in **Figure 2**.

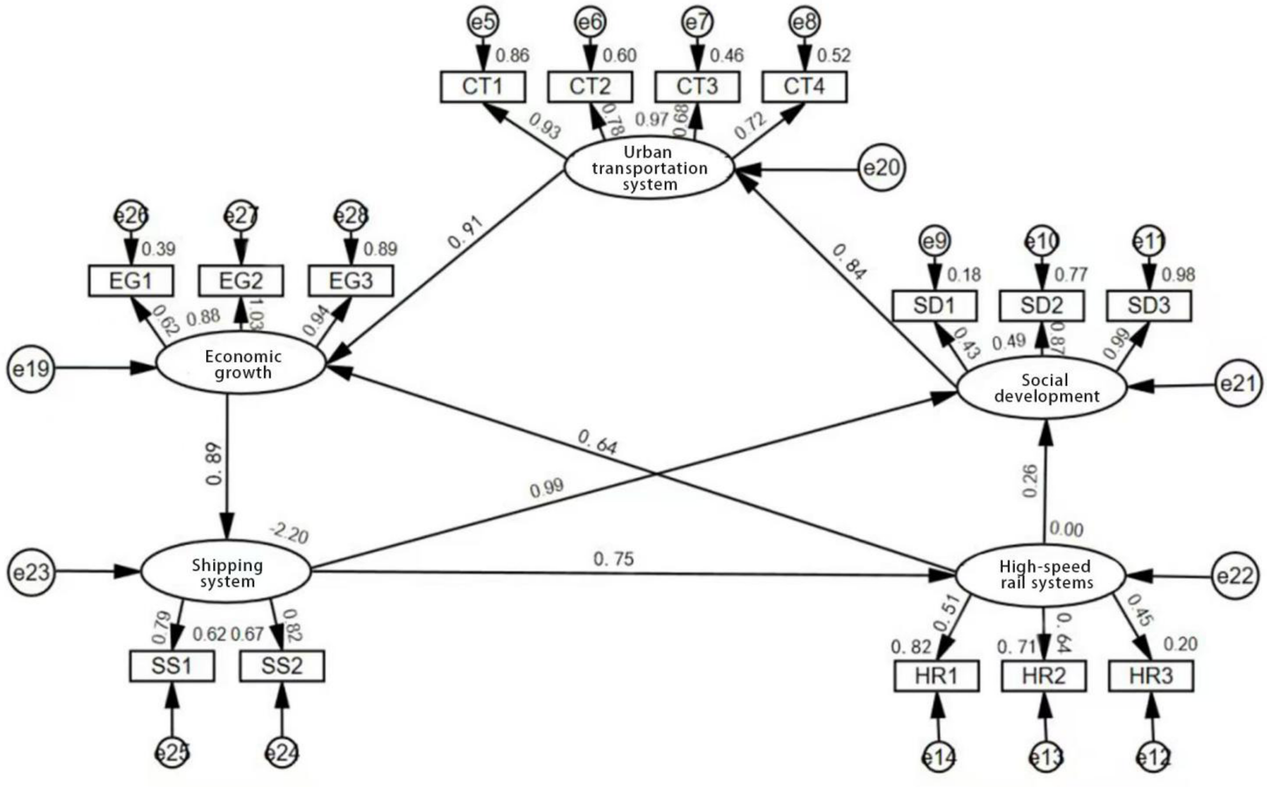

Figure 2. Schematic representation of the structural equation model

3.2. Data Analysis

3.2.1 Descriptive statistical analysis

Usually, the structural equation model (SEM) analysis requires the ratio between the number of variables and the sample size to be at least 1:10 to ensure the estimation accuracy and reliability of the model. In this paper, considering that the total number of samples is 310 data points, far exceeding the minimum proportion required, indicating that the amount of data used in this paper fully meets the basic requirementWs of structural equation model construction. Accordingly, we performed a descriptive statistical analysis, and the results are shown in **Table 3**.

Table 3. Descriptive statistics of the study variables

Variable name	Sample capacity	Least value	Crest value	Average value
EG1	310	22089	190313	62048.65
EG2	310	828.20	129513.60	28276.7723
EG3	310	63.90	47688.40	9548.5642
SD1	310	9740	79610	27246.17
SD2	310	17.5	1166.2	246.431
SD3	310	826102	60188062	12081176.52
CT1	310	366	68535	14621.46
CT2	310	5296	1098428	251961.54

Table 3 (Continued)

Variable name	Sample capacity	Least value	Crest value	Average value
CT3	310	308	31757	7308.54
CT4	310	124	5647	1975.82
HR1	310	.05	1.42	.4227
HR2	310	129	38699	8522.19
HR3	310	43	104514	13186.08
SS1	310	372	134402	18862.35
SS2	310	857.0	3110950.0	190882.763

3.3. Reliability and validity tests

3.3.1. Reliability test

In this paper, the Klonbarach coefficient (Cronbach's α) is used as the standard to test the credibility of the questionnaire. The value range is between [0,1], and the greater the value, the higher the credibility [14]. In general, an α value greater than 0.7 was considered acceptable. The results of the reliability test are shown in **Table 4**.

Table 4. Reliability test

Latent variable	Observable variable	Variable number	Cronbach's α
Economic growth	Per capita GDP	EG1	0.799
	Regional GDP	EG2	
	Value added	EG3	
Social development	Per capita disposable income of all residents	SD1	0.780
	Urban employment	SD2	
	Educational appropriations	SD3	
Shipping system	Employment in the air transport industry	SS1	0.842
	Total length of air mail road	SS2	
High-speed railway system	Railway mileage	HR1	0.863
	Railway passenger traffic volume	HR2	
	The volume of railway freight	HR3	
Urban transportation system	Number of public transport vehicles operated	CT1	0.885
	Public transport passenger volume	CT2	
	The number of traffic accidents that have occurred	CT3	
	Number of deaths in traffic accidents	CT4	

According to the reliability test of **Table 4**, it can be seen that the reliability of the five potential variables is greater than 0.7, which means that the questionnaire has high trust and reliability and meets the requirements.

3.3.2. Validity test

Validity tests are usually performed using Kaiser-Meyer-Olkin (KMO) measurement and Bartlett test of sphericity. The test results are shown in **Table 5**.

Table 5. KMO and Bartlett tests

Number of KMO sampling suitability quantities		0.878
Bartlett sphericity test	Chi-square value	8568.177
	Free degree	95
	Conspicuousness	0.000

According to **Table 5**, the KMO and Bartlett standard tests were conducted on the questionnaire data using Statistical Package for the Social Sciences (SPSS) 28.0. The KMO value was 0.878, greater than 0.7, so the study data was very appropriate, and the significance probability of the Bartlett sphericity test was 0.000, far less than 0.005, so the variable correlation was good, thus exploratory factor analysis can be conducted on the data.

4. With a moderate test

Amos software is used to bring data into the model for verification and correction. Because the significance of the chi-square value is susceptible to many factors, a variety of adaptation index values need to be used for comprehensive tests. In this paper, chi-square/degree of freedom, Goodness-of-Fit Index (GFI), Adjusted Goodness-of-Fit Index (AGFI), Root Mean Square Error of Approximation (RMSEA), Incremental Fit Index (IFI), Comparative Fit Index (CFI), Tucker-Lewis Index (TLI), and Normed Fit Index (NFI) are the main reference evaluation indicators to test the fit of the model.

Table 6. Index values of the structural equation model

Adaptation index	Recommended value	Fitted value
χ^2/df	1–3	1.693
GFI	$>$ 0.9	0.912
AGFI	$>$ 0.8	0.829
RMSEA	$<$ 0.08	0.007
IFI	$>$ 0.9	0.919
CFI	$>$ 0.9	0.967
TLI	$>$ 0.9	0.981
NFI	$>$ 0.9	0.984

The results are shown in **Table 6**, assuming a high fit between the model and the data, the data analysis results are acceptable.

5. Analysis of model results

5.1. Standardized pathway analysis between each latent variable

The standardized path coefficient is an indicator that can be used to measure the strength of the relationship between the latent and observed variables, and its magnitude represents the degree of correlation between the two variables. If the standardized path coefficient is large, it indicates a strong correlation between the two variables. The operation results of the Amos software are shown in **Table 7** and **Figure 3**, and there is a significant interaction between the transportation system and socio-economic development. The positive relationship between economic growth and the shipping system (standardized path coefficient = 0.91) is strong, indicating that the development of the shipping system can significantly promote economic growth. Similarly, the positive link between the urban transportation system and social development (standardized path coefficient = 0.84) also confirms that the optimization of transportation infrastructure can effectively promote the improvement of social welfare. Additionally, the high-speed railway system positively impacts economic growth (standardized path coefficient = 0.64) and social development (standardized path coefficient = 0.26), although its impact on social development is relatively small. The direct promotion effect of the shipping system on social development (standardized path coefficient = 0.99) is the most significant in the model, emphasizing the core role of shipping in the socio-economic system. The contribution of the urban transportation system to economic growth (standardized path coefficient = 0.91) is similar to that of the shipping system, which further verifies the importance of transportation system optimization to economic dynamics. The positive relationship between the shipping system and the high-speed railway system (standardized path coefficient = 0.75) reveals the importance of the complementarity and integration between different traffic modes for the efficiency of the overall traffic network.

Table 7. Results of hypothesis testing

Item	Relation	Standardized path coefficient	Significance	Conclusion
H1	Economic growth in the shipping system	0.91	***	found
H2	Social development of the urban transportation system	0.84	***	found
H3	Economic growth of the high-speed railway system	0.64	***	found
H4	Social development of the shipping system	0.99	***	found
H5	Social development of the high-speed railway system	0.26	***	found
H6	Economic growth of the urban transportation system	0.91	***	found
H7	Shipping system High-speed railway system	0.75	***	found

Note：*** is $P < 0.001$

5.2. Results of the model fit between the latent variables

The model-fitting results among the latent potential variables are shown in **Figure 3**.

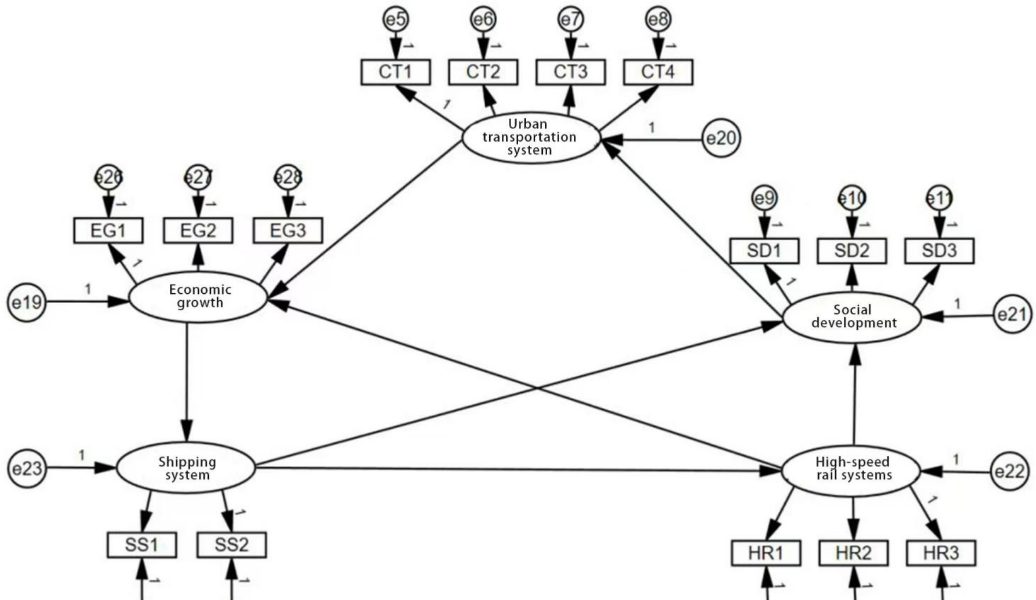

Figure 3. Schematic representation of the model-fitting results

6. Conclusion

In this paper, we explore the interactive influence between the transportation system and socio-economic development through the structural equation model (SEM), and the results emphasize the importance of transportation infrastructure to promote economic growth and social welfare. The study reveals the core role of the shipping system, high-speed railway system, and urban transportation system in promoting social and economic development, and points out the demand for social and economic development levels to optimize the construction of transportation systems. Through this study, expectations can provide empirical support for policymakers in planning and optimizing transportation infrastructure to support economic and social progress, providing a new perspective on understanding the complex relationship between transportation and socio-economic development.

Disclosure statement

The authors declare no conflict of interest.

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