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Research on the Travel Efficiency and Satisfaction Characteristics of the Chang-Zhu-Tan Intercity Railway Residents and Its Influencing Factors

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Abstract: *The role of intercity railway in accelerating the development of regional integration in Chang-Zhu-Tan region is becoming more and more obvious. This paper focuses on the Chang-Zhu-Tan intercity railway, and sets up two simulation scenarios based on the spatial equity efficiency impact model. A questionnaire survey was conducted on the socio-economic attributes and intercity travel characteristics of residents traveling by intercity railway, and quantitative and qualitative analysis was carried out by using the "door-to-door" travel time measurement method and economic potential index, so as to obtain the comparison of residents' satisfaction with intercity railway travel and travel fairness. The results show that occupation has a significant positive impact on intercity railway travel satisfaction. The three categories of "fast speed and less time consuming", "high punctuality of trains" and "unusable by private cars" all have a significant impact on the satisfaction of intercity railway travel. This paper quantitatively evaluates the radiation driving effect of intercity railway development, and provides empirical enlightenment for the government to optimize intercity railway services, accelerate the transformation of transportation capacity economic achievements, and promote the development of regional integration in the context of transportation power.*

Keywords: *Intercity Railway; Travel Satisfaction; Travel Efficiency; Mobility Fairness*

1. Introduction

With the development of the economy, multimodal transportation has provided travelers with more options for their journeys, while also making the travel experience more complex, making it more difficult to measure travel satisfaction and efficiency. Based on this, this article intends to explore the characteristics and influencing factors of intercity rail travel efficiency and satisfaction among residents of Chang-Zhu-tan.

The research on the fairness of public transport by foreign scholars mainly focuses on two dimensions: the difference in the level of supply and demand of public transport, and the impact of changes in the supply of public transport. At present, in the research of foreign scholars, the prediction models of travel mode division mainly include Aggregate Model and Disaggregate Model. The Disaggregate Model, also known as the Discrete Choice Model (DCM), can be divided into Probit model and Logit model, among which the Logit model has been widely used by scholars at home and abroad in the study of selective behavior of travel modes[1].

Domestic scholars put forward relevant concepts around practical problems, analyzed different modes of transportation, learned from international experience, and proposed corresponding improvement measures. In general, most of the existing studies focus on the elaboration of macro concepts and the construction of theoretical frameworks, while there are relatively few empirical analyses based on specific data[2]. Domestic research mainly focuses on the following three directions: First, the Logit model is used to study the matching of supply and demand of various modes of transportation in the transportation system. For example, scholars such as Zhang Bing, Guo Qianqian, and Feng Yan have constructed a sharing rate model[3] based on the characteristics of passenger travel or the service attributes of transportation modes, and analyzed the distribution of passenger flow in transportation corridors. Secondly, on the basis of the Logit model, the influencing factors of travelers' transportation mode

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transfer behavior are discussed. Ye Yuling, Chen Junli and other scholars used the Logit model to study the impact of traveler attributes on bus travel choices[4], Hang Xuan analyzed the transfer behavior of transportation hub passengers[5], Xu Jingjun used the Logit model to explore the influencing factors of high-speed rail passenger behavior choices based on the planning behavior theory[6]. Finally, the key factors of travel mode choice under different scenarios are studied. For example, Yuan Pengwei used the NL model to identify the main factors influencing the choice of travel mode by combining travel characteristic variables, weather state variables, and socioeconomic variables.[7]

This paper analyzes the satisfaction and efficiency of intercity railway travel of residents in Chang-Zhu-Tan region, summarizes the characteristics of residents' intercity travel, and puts forward some optimization suggestions. The development and construction of intercity railways will effectively promote the balanced allocation of inter-city transportation resources, improve the convenience and comfort of urban residents, promote urban economic and cultural interactions, and provide important guarantees and supports for the sustainable development of urban transportation.

2. Overview of the study area and data sources

2.1. Overview of the study area

This research takes the Chang-Zhu-Tan region as the research scope, including the whole area of Changsha, Zhuzhou and Xiangtan, and the distance between any two city centers is less than 50 kilometers, which is the core growth pole of Hunan's development.

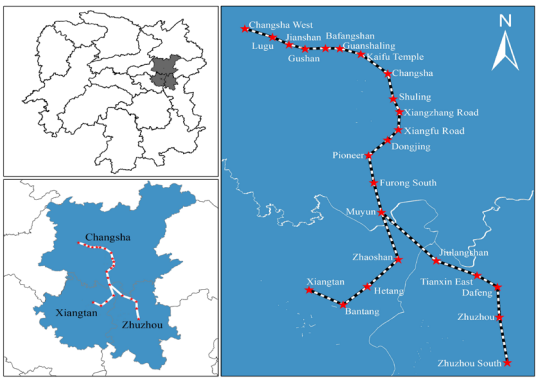

Figure 1 Location of Chang-Zhu-Tan region and Chang-Zhu-Tan region intercity railway

In this research, the intercity railways passing through Chang-Zhu-tan are taken as the research objects. The railway is laid out in the shape of a "person" (Figure 1) in Chinese, starting from the south end of Changsha Station, extending south to Muyun, and then divided into two branches, connecting to Zhuzhou and Xiangtan stations respectively; The west line crosses the Xiangjiang River to Lei feng Avenue. The westward section leads out from the north end of Changsha Station, runs parallel to the Beijing-Guangzhou Railway, turns into an underground tunnel at Deya Road, crosses Dongfeng Road and Furong North Road in turn, extends westward along Kaifu Temple Road, crosses the Xiangjiang River through Dujuan Road, and reaches the Gushan Station on the north side of Changsha Municipal Government. The southbound section leads from the south end of Changsha Station, enters the underground tunnel from Shuling in the south, and then exits the tunnel from the South Bus Station, and the viaduct extends along the old National Highway 107 and Furong South Road to Muyun Station. From Muyun Station to the south, a viaduct along the east side of the Beijing-Guangzhou Railway passes through Baima Ridge, along Hongqi Road in Zhuzhou City to Baishi Port, passes through Xinhua West Road to Zhuzhou Station; The other west crosses the Beijing-Guangzhou Railway, the viaduct passes through Zhaoshan, crosses the Hetang and Bantang along the Furong Avenue in the east, and enters Xiangtan Station after crossing the Xiangjiang River.

2.2. Data Sources and Processing

The administrative division data is derived from the vectorization of Changsha, Zhuzhou and Xiangtan maps, and the intercity railway data is obtained by vectorizing the road data of Hunan Province. The travel time data is derived from Baidu Maps, and the Baidu Maps API data is manually checked to supplement the missing data and incomplete data points. Population data are derived from the 2023

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Statistical Yearbooks of Chang-Zhu-Tan Cities[8]. The satisfaction data were derived from the questionnaire survey after screening, and some questionnaires with travel characteristics that were not in the study area and key information were missing were screened out.

3. Research Framework and Model Construction

3.1. Research framework

In response to spatial equity and efficiency of intercity railways in different contexts, we construct an analytical framework based on key indicators of regional transport networks, population distribution, and economic development. First, by utilizing the weighted travel time model and economic potential assessment tools, we delve into the potential impacts of intercity railways on regional spatial equity. Next, based on different scenario settings (scenarios without intercity railways and the current intercity railway scenario), we assess the degree of improvement in spatial efficiency. Finally, by comparing the changes in spatial variance coefficients before and after construction, we reveal how the planning of intercity railways influences the spatial equity situation in various regions.[9]

In order to further explore the performance of intercity railways in spatial equity and efficiency in various contexts, we designed a multi-dimensional analytical framework, with a special focus on regional transportation network structure, population distribution, and regional economic development dynamics, as the core data drivers. Based on the complex model of weighted travel time[10] and economic potential[11] , this paper analyzes the reasons for the influence of intercity railways on regional spatial equity. By comparing the changes in spatial efficiency before and after construction, especially by analyzing the significant differences in the coefficient of variation, we systematically evaluate the actual effectiveness of intercity railways in improving spatial efficiency, which is a key indicator to measure the changes in spatial equity, and is used to judge the specific impact of intercity railway planning schemes on spatial equity in different regions.

A study on residents' satisfaction with travel utilized a questionnaire survey method to investigate the socio-economic attributes of residents' intercity travel, the characteristics of intercity travel, and travel satisfaction[12].The characteristics of intercity travel and travel satisfaction in Chang-Zhu-Tan region were qualitatively described, and SPSS26.0 was quantitatively analyzed. The research on the efficiency of residents' travel employs a stratified fishing net cost measurement method, rasterizing various levels of roads and buffer zones to form multiple raster surfaces of roads and buffer zones; it calculates the required time for passing through each raster unit; and overlays each raster unit sequentially according to the travel model. For the Chang-Zhu-Tan region, a 5km×5km fishing net unit was selected, dividing it into 448 homogeneous fishing net units. To calculate travel time, the "door-to-door" travel time measurement method (the total travel time from one departure point to one destination) is used.

3.2. Model construction

3.2.1. Construction of "door-to-door" travel time calculation model

Taking railway travel as an example, the overall travel timeT_{os} can be divided into four parts: the timeT_{ts} from the departure point to the nearest railway station, and the transfer timeT_{ss} between the two railway stations, including waiting, transferring, and exiting; the durationT_{sd} of the railway operation between the two stations; The total time spent from the nearest station i to the destination j is calculated as follows:

$$\mathrm{T_{ij}} = \mathrm{T_{os}} + \mathrm{T_{ts}} + \mathrm{T_{ss}} + \mathrm{T_{sd}} \tag{1}$$

When planning a trip, travelers often compare the time taken by various modes of transportation to choose the fastest way to travel, so the formula for calculating the accessibility from the departure point o to the destination m is:

$$T_{ij} = \min\left(T_{ij}^{c}, T_{ij}^{t}, T_{ij}^{p} \ldots\ldots\right) \tag{2}$$

where: $T_{ij}$is the level of accessibility between i j and the two places;T_{ij}^{c},T_{ij}^{t},T_{ij}^{p}which is the total travel time spent in different travel modes. [9]

3.2.2. Evaluation indicators

(1)Weighted average travel time

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Weighted average travel time is the average of the minimum travel time required to travel from one area to another, and this metric focuses on the cost of time to assess accessibility. The formula is as follows:

$$AT_i = \sum_{j=1}^{n}(T_{ij} \times M_j)/\sum_{j=1}^{n} M_j \quad (3)$$

AT_i is the lower the value of the weighted average travel time of region i; T_{ij} Indicates the minimum travel time from region i to region j; The variable M_j represents the scale of the flow of socio-economic factors in region j within the research scope, and this paper adopts the geometric mean of the population P_i of each node region as the weight; n is the number of nodes in the research area.

(2)Economic potential index

The Economic Potential Index is an indicator used to measure the economic growth and development possibilities of a region, country or enterprise in the future. [13] Through this model, we can deeply analyze how the opening of intercity railways can bring unique location advantage potential to regional space. The formula is as follows:

$$PA_i = \sum_{j=1}^{n}(M_j/T_{ij}) \quad (4)$$

The larger the value, the stronger the economic radiation capacity PA_i of region i. M_j is the population size of region j; T_{ij} is the shortest travel time from region i to region j. [9]

4. Research on the satisfaction of residents in Chang-Zhu-Tan region with intercity railway travel

4.1. Questionnaires and descriptive content analysis

4.1.1. Survey Purpose and Survey Methodology

According to the purpose of the study, a questionnaire was designed to obtain the relevant information of the intercity travel of the surveyed residents through a questionnaire survey of the residents in the Chang-Zhu-Tan region, so as to analyze the characteristics and satisfaction of the residents in the Chang-Zhu-Tan region, and put forward relevant suggestions on this basis, so as to improve the intercity transportation system and improve the satisfaction of the residents in the Chang-Zhu-Tan region.

The questionnaire survey method was used to investigate the satisfaction of residents in Chang-Zhu-Tan region to carry out intercity railway travel, and more than 380 valid questionnaires were collected. The questionnaire in this study is divided into three dimensions: basic information, travel information, and satisfaction information, with a total of 26 items, including the personal attributes of travelers (gender, age, income, whether they own a car, etc.), intercity travel characteristics (the departure and departure time of the most recent cross-city trip, the destination station and destination, the mode of transportation from the departure place to the station, etc.), and the satisfaction of intercity travel.

4.1.2. Descriptive analysis of the content of the survey

Descriptive analysis refers to the overall picture of data through the mean or median. The data obtained from the questionnaire were analyzed descriptively, and the results obtained are shown in Table 1. It can be seen that there are no outliers in the data obtained through the questionnaire. Therefore, the obtained questionnaire data can be subsequently analyzed.

Table 1. Descriptive analysis of the survey content

Name	Sample size	Min	Max	Mean value	Standard deviation	Median
gender	380	1.000	2.000	1.555	0.498	2.000
age	380	1.000	6.000	2.950	1.139	3.000
Educational background	380	1.000	5.000	3.411	1.058	4.000
occupation	380	1.000	8.000	5.153	2.441	7.000
Average monthly income	380	1.000	6.000	2.268	1.183	2.000
Whether you own a car	380	1.000	2.000	1.663	0.473	2.000
How to travel to and from the destination and station	380	1.000	5.000	1.863	1.093	2.000
Intercity transportation is convenient	380	1.000	8.000	1.803	1.473	1.000
Intercity rail travel satisfaction	380	1.000	4.000	1.603	0.619	2.000
Purpose of intercity travel	380	1.000	6.000	3.753	1.707	3.000

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4.2. Analysis of the personal attributes of intercity travelers in the Chang-Zhu-Tan region

The personal attributes of intercity travelers mainly include gender and age, occupation and education, average monthly income, and whether they own a car. Table 2 presents the statistical results of the personal attributes of intercity travelers.

Table 2. Statistical results of personal attributes of intercity travelers

Stats	Trait	Statistical result(%)
gender	male	44.47%
	female	55.53%
Age	Under 18 years old	6.32%
	18-22 years old	35.53%
	23-30 years old	26.84%
	31-45 years old	20.53%
	46-60 years old	9.73%
	Age 60 and above	1.05%
Educational background	Junior high school and below	6.32%
	Senior high schools	16.05%
	Junior college	16.58%
	Undergraduate course	52.37%
	Graduate (Master, doctor and above)	8.68%
occupation	Civil servants (including public institutions)	9.47%
	Employees of state (central) enterprises	9.74%
	Private employee	16.32%
	Individual industrial and commercial households	7.11%
	Retired personnel	2.37%
	Work/farm	2.37%
	Pupil	38.15%
	freelancer	14.47%
Average monthly income	2000 yuan and below	36.32%
	2001-5000 yuan	19.21%
	5001-10000 yuan	30.00%
	10001-15000 yuan	11.05%
	15001- 100,000 yuan	2.63%
	More than 100001 yuan	0.79%
Whether you own a car	Yes	33.68%
	No	66.32%

4.3. Analysis of intercity travel characteristics of intercity travelers in Chang-Zhu-Tan region

The travel characteristics of intercity travelers mainly involve the purpose and mode of travel[14].

4.3.1. Purpose of travel

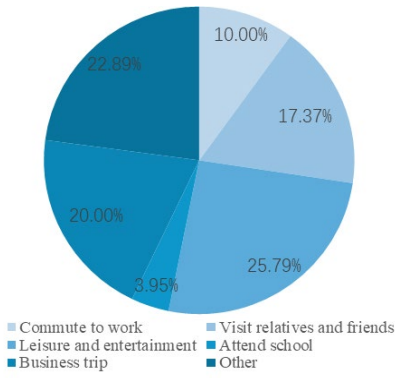

Figure 2 Distribution of the purpose of intercity travel of residents in the Chang-Zhu-Tan region

As can be seen from Figure 2, from the perspective of the composition characteristics of intercity travel purposes in the Chang-Zhu-Tan region, the highest proportion is leisure and entertainment,

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accounting for 25.79%; The proportions of others and business trips were relatively close, with 22.89% and 20.00% respectively. Further analysis of the data obtained from the questionnaire survey shows that the proportion of non-flexible travel such as commuting to work, school and business trip is 33.95%, and it can be concluded that the intercity travel in Chang-Zhu-Tan region is mainly based on flexible travel.

4.3.2. How to get around

Through the questionnaire survey, it can be found that in the process of traveling between the destination and the station, 48.42% and 31.05% of travelers choose taxis and public transportation, respectively. The proportion of intercity travelers who chose private cars was relatively small, only 11.05%; A very small number of intercity travelers surveyed chose bicycles/motorcycles to travel and walk because of the different average monthly income levels of travelers and the large differences in convenience, comfort, safety and charging levels between different modes of travel.

As shown in Table 3, the choice of travel mode between destinations and stations is different among the intercity travelers surveyed by different occupational groups. In general, public transport and taxis, followed by private cars, and fewer people choose bicycles/motorcycles and walking. Therefore, it is indispensable to take the lead in the development of public transportation in the actual choice of travel modes between destinations and stations in the process of intercity travel in Chang-Zhu-Tan region.

Table 3. Distribution of intercity travel modes of different occupational groups

Occupational group	Public transport	Taxi	Private car	Bicycle/Motorcycle	Walking
Civil servants	55.56%	22.22%	11.11%	2.78%	8.33%
Employees of state (central) enterprises	64.86%	21.62%	10.81%	0.00%	2.71%
Private employee	56.45%	25.81%	6.45%	1.61%	9.68%
Individual business operator	51.85%	25.93%	18.52%	3.70%	0.00%
Retired personnel	55.56%	11.11%	0.00%	11.11%	22.22%
Work/farm	33.34%	33.33%	0.00%	11.11%	22.22%
Student	38.62%	41.38%	11.03%	6.21%	2.76%
freelancer	49.10%	27.27%	16.36%	7.27%	0.00%

4.4. Analysis of satisfaction characteristics of intercity railway travel in Chang-Zhu-Tan region

4.4.1. Intercity railway travel satisfaction under the condition of intercity travel characteristic factors

The nonparametric test was used to study the difference between the purpose of intercity travel and the satisfaction of intercity railway travel, and the results obtained are shown in Table 4. Because the number of categories for intercity travel purposes is greater than 2, the Kruskal-Wallis test statistic [15] is used for analysis. The samples of different intercity travel purposes all showed a significant effect on the satisfaction of intercity railway travel ($P<0.05$), which means that different intercity travel purposes have differences in the satisfaction of intercity railway travel.

Table 4. Results of non-parametric test analysis of intercity travel purpose and intercity railway travel satisfaction

	Median intercity travel destination M (P25, P75)						Kruskal-Wallis Test statistic *H*	*p*
	Commute to work	Visit relatives and friends	Recreational activities	Attend school	Business trip	Other		
Intercity rail travel satisfaction	1.000	2.000	2.000	1.000	2.000	2.000	24.327	0.000**
* $p<0.05$ ** $p<0.01$								

4.4.2. Intercity travel satisfaction under the condition of individual attribute factors

The correlation between intercity travelers' satisfaction with intercity railway travel and individual attribute factors is analyzed, and the significance level is used to predict the probability that the overall parameters may be wrong within a certain range. The Pearson correlation coefficient[16] is used to represent the strength of the correlation, and the results are shown in Table 5. Through specific analysis, it can be seen that the correlation coefficient between intercity railway travel satisfaction and occupation is 0.114, and shows a significance of 0.05 level, indicating that there is a significant positive correlation between intercity railway travel satisfaction and occupation. There is no correlation between personal

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attributes such as gender, age, education level, average monthly income, and whether one owns a car.

Table 5. Pearson correlation analysis of intercity railway travel satisfaction and individual attributes

	Sample size	p-value	Correlation coefficient
Gender	380	0.636	0.024
age	380	0.361	-0.047
Educational background	380	0.876	0.008
occupation	380	0.027	0.114*
Average monthly income	380	0.863	-0.009
Whether you own a car	380	0.109	0.082

Using occupation as the independent variable and intercity rail travel satisfaction as the dependent variable for linear regression analysis, the results obtained are shown in the table 6. It can be seen that, the model formula is: $\text{Intercity rail travel satisfaction} = 1.454 + 0.029 * \text{occupation}$, and the model R square value is 0.013, which means that occupation can explain the 1.3% change in intercity rail travel satisfaction. The results of F=4.946, p=0.027<0.05 were obtained by the F test, indicating that the construction of the model was meaningful. This also shows once again that occupation will definitely have an impact on the satisfaction of intercity rail travel. According to the final specific analysis, the regression coefficient of occupation is 0.029 (t=2.224, p=0.027<0.05), which means that occupation has a significant positive impact on the travel satisfaction of intercity railway.

Table 6. Linear regression analysis results of intercity railway travel satisfaction and occupation

	Non-normalized coefficients		Normalization factor	*t*	*p*	Collinearity Diagnosis	
	B	Standard error	*Beta*			VIF	Tolerance
constant	1.454	0.074	-	19.706	0.000**	-	-
occupation	0.029	0.013	0.114	2.224	0.027*	1.000	1.000
R^2	0.013						
Adjust R^2	0.010						
F	F (1,378)=4.946,p=0.027						
D-W	0.734						
Dependent variable: Intercity rail travel satisfaction				* *p<0.05* ** *p<0.01*			

4.4.3. Analysis of the current situation of intercity railway travel satisfaction in Chang-Zhu-Tan region

Correlation analysis is used to study the correlation between intercity railway travel satisfaction and intercity transportation convenience, and the A correlation coefficient is used to express the strength of the correlation. The result obtained: The correlation coefficient between intercity railway travel satisfaction and intercity transportation convenience is 0.103, and it shows significance at the 0.05 level. The results indicate that there is a significant positive correlation between intercity railway travel satisfaction and intercity transportation convenience. The chi-square test was used to study the differential relationship between intercity transportation convenience and intercity railway travel satisfaction. [9] From Table 7. it can be seen that different samples of intercity transportation convenience show a significant difference in intercity railway travel satisfaction (P<0.05), which means that different samples of intercity transportation convenience show differences in intercity railway travel satisfaction. The satisfaction with intercity railway travel was 0.01 (x 2=74.377, p=0.001<0.01). By summarizing, it can be seen that there are significant differences in the travel satisfaction of intercity railways with different intercity transportation conveniences.

Table 7. Results of chi-square analysis of intercity railway satisfaction and intercity transportation convenience

	Fast	Reasonable ticket prices	Good environment	The other tickets are sold out	total	x 2	p
Very satisfied	129	16	15	1	175	74.377	0.000 **
Ordinary	113	23	31	1	184		
Relatively dissatisfied	14	1	1	0	18		
Very dissatisfied	0	0	2	1	3		
	Ticket reimbursement	High punctuality	Private cars are not available	other			
Very satisfied	1	8	5	0	175		
Ordinary	9	5	0	2	184		
Relatively dissatisfied	1	1	0	0	18		
Very dissatisfied	0	0	0	0	3		

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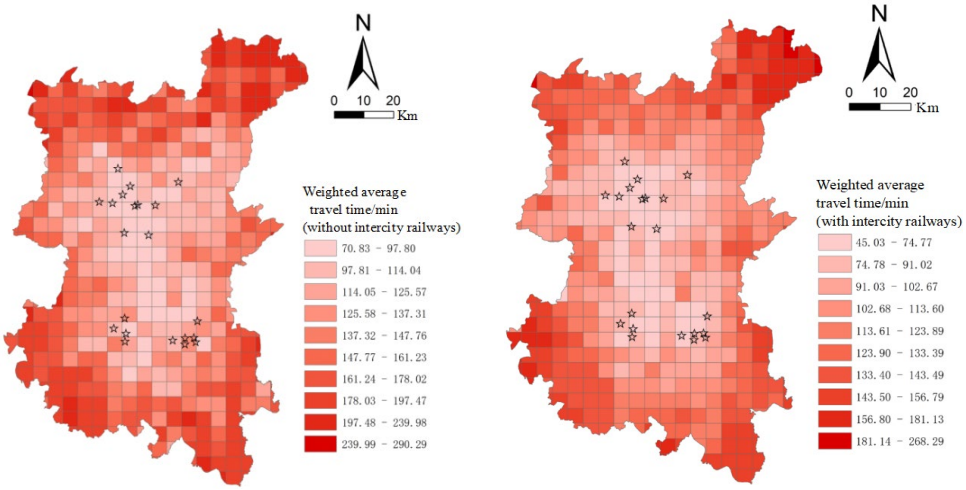
5. Analysis of residents' travel efficiency and economic potential of Chang-Zhu-Tan intercity railway in different scenarios

5.1. Analysis of residents' travel efficiency

The operation of the Chang-Zhu-Tan Intercity Railway has significantly improved the connectivity of the three cities along the line in terms of time and space. However, in view of the differences between these three cities in terms of population size, economic strength, degree of agglomeration, geographical location and their respective functional positioning, there are also some differences in the improvement of time and space distance accessibility brought by intercity railways.[17]

The Chang-Zhu-Tan Intercity Railway has established up to 12 stations in Changsha, while Xiangtan and Zhuzhou each have only 4 and 5 stations respectively, highlighting Changsha's status as the central hub of the intercity railway network.[18]And some of these stations are located in the city's bustling business districts, making it easy for the city to receive the flow of people, goods, and information from Zhuzhou and Xiangtan. This superior geographical location and perfect transportation network make Changsha occupy an absolute advantage in the accessibility of time and space.[19] Relatively speaking, Xiangtan and Zhuzhou have a relatively single role in the intercity railway network due to their geographical location and economic strength. These two cities are mainly used as the radiation area of Changsha, and the ability to receive resources is strong, but the output capacity is limited. Therefore, in terms of spatiotemporal distance accessibility[20], Xiangtan and Zhuzhou are slightly inferior to Changsha.

Weighted average travel time of the three cities of Chang-Zhu-Tan before and after the construction of the intercity railway and comprehensive weighted average travel time of the local representative businesses before and after the construction of the Chang-Zhu-Tan region intercity railway the spatial efficiency characteristics of Chang-Zhu-Tan region under different scenarios of intercity railway construction are further analyzed (Figure 3). It is concluded that intercity railway trend and relative location relationship are significantly correlated with the difference of OL attainment level in different regions.[21]



a. Weighted average travel time without intercity railways

b. Weighted average travel time with intercity railways

Figure 3 Weighted average travel time (AT) in Chang-Zhu-Tan region before and after the construction of intercity railway

In the absence of intercity railways, Changsha, as a regional central city, has the shortest weighted average travel time in its central area. As the distance from the center increases, the weighted average travel time gradually increases, showing a downward trend towards the outer circle.[22] Zhuzhou and Xiangtan are important cities around Changsha, and although their central areas are also well connected, the marginal areas of these two cities may have longer weighted average travel times due to their relatively underdeveloped transportation networks. After the completion of the intercity railway, there were significant changes. The weighted average travel time in most parts of Changsha has been reduced to less than 120 minutes, thanks to the efficiency and convenience of intercity railways. However, in the north, where there is no intercity railway, it still relies on the original transportation network, and the change in weighted average travel time is relatively small. For Zhuzhou and Xiangtan, the weighted

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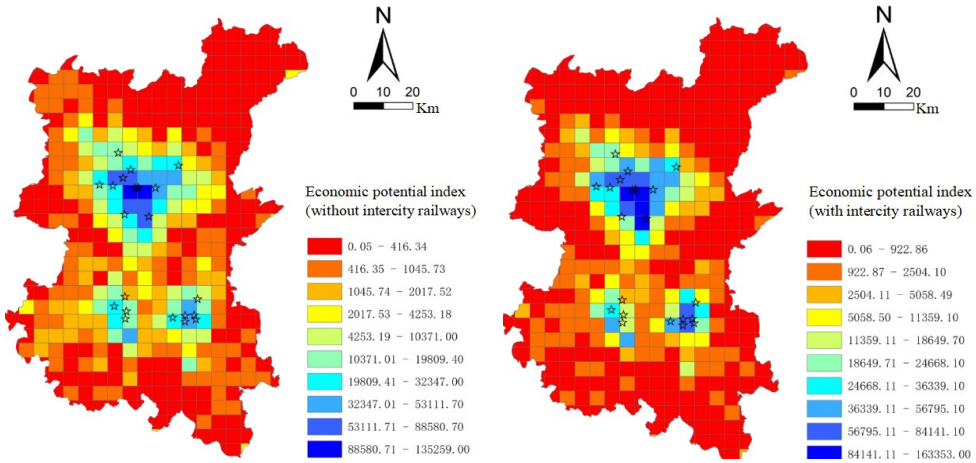
average travel time in some areas has been significantly reduced, which means that travel times have been reduced and access rates have become higher in areas along the three cities.

5.2. Analysis of regional economic potential

With the increasing radiation capacity of regional economic centers, the differences in economic development potential between regions are becoming more and more obvious, showing a trend of polarization.[23] In order to meet this challenge, the planning and construction of intercity railway networks is particularly crucial.[24] The planning and construction of intercity railway networks not only effectively improve the external environment for spatial economic and social development but also significantly enhance economic connections and interactions between neighboring regions, thereby achieving the goal of optimizing regional spatial resource allocation and promoting balanced economic development. The planning and construction of intercity railways has gradually promoted the diffusion of the economic potential advantage areas in the Chang-Zhu-Tan region from Changsha to the Adjacent deep into the areas of Zhuzhou and Xiangtan, and the regional nodes show a trend of network agglomeration under the guidance of transportation (Figure. 4).[25]



a. Index of economic potential without intercity railways

b. Index of economic potential with intercity railways

Figure 4: Economic potential index before and after the completion of the Chang-Zhu-Tan region intercity railway

Changsha's economic potential has significantly surpassed Zhuzhou and Xiangtan before and after the operation of the high-speed railway, and there are many reasons behind this. As the economic and political center and transportation center of Chang-Zhu-Tan region, Changsha has a convenient transportation network and perfect transportation facilities, and its unique position makes it enjoy significant advantages in resource allocation and policy support, thus providing a solid foundation for its economic development.[26] Xiangtan has the lowest potential value for high-speed rail among the three cities. This is not only because its economic strength is relatively weak, but also due to the constraints of geographical location, and Zhuzhou, as an important railway hub on the Beijing-Guangzhou line, has a significantly better transportation location. It can be clearly observed from Figure 4 that the economic potential of high-speed railways in Xiangtan and Zhuzhou did not grow significantly before and after the commissioning of the intercity railway, and the gap in the growth rate was relatively limited, which further emphasized the central position of the intercity railway in strengthening the connection between Changsha and its surrounding cities.

6. Conclusions and Recommendations

6.1. Conclusion

Regarding spatial equity and efficiency:①The Chang-Zhu-Tan intercity railway breaks the barriers of regional travel, enhances residents' travel efficiency, expands their living circles, and increases their sense of well-being.②The travel time from each city along the line to other regions has been shortened, improving regional accessibility and promoting the integrated development of the Chang-Zhu-Tan area, thereby narrowing the development gap between regions.③It has exacerbated the differences in

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economic development potential, with the growth rate of economic development potential in peripheral areas being relatively low, and there is a distance decay effect in the flow of intercity elements along transportation corridors.

Regarding travel satisfaction:①In terms of intercity travel characteristics, there are significant differences in the satisfaction of intercity travelers with intercity rail based on different travel purposes. ②Occupation has a significant positive impact on intercity rail travel satisfaction, and occupation can explain 1.3% of the variation in intercity rail travel satisfaction.③In terms of transportation convenience, only travelers categorized as “fast speed” “high punctuality of trains” and “private car unavailable” have an average level of being “very satisfied” with intercity rail.

6.2. Recommendations

According to the conclusions, three major recommendations have been proposed for the future development of the Chang-Zhu-Tan intercity railway. ①Improve the public transportation network and services: To address the issue of insufficient public transportation in remote areas, it is recommended to strengthen public transport coverage and enhance travel equity and accessibility. ②Optimize intercity railway operation and experience: It is suggested to simplify the ticket purchasing and boarding process for the intercity railway, attracting more passengers to choose intercity railway travel, reducing the vacancy rate, lowering carbon emissions, and supporting regional green development. ③Promote regional integration and coordinated development: The construction of the intercity railway should guide core cities to expand towards new areas, suburbs, and surrounding towns, optimizing the transportation system and promoting resource sharing.

By improving public transportation, optimizing intercity railway operations and promoting regional integration, the Chang-Zhu-Tan region will achieve comprehensive development of the transportation network and regional economy, improve the travel experience of residents, provide strong support for regional green development and resource sharing, and promote the overall competitiveness of the Chang-Zhu-Tan region.

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