Coupling relationship between transportation and tourism systems—a case study in the Huizhou City, China

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Abstract. Coupling relationship between transportation and tourism systems is significant to the sustainable development of regional economy, society and environment. Based on the coupling coordination degree model and scenario analysis method, the coupling relationship between transportation and tourism systems in the Huizhou City was studied in this research. The results showed that during 2014 and 2015, the coupling coordination degree between the two systems in the Huizhou City was at a moderate imbalance level. In terms of the districts and counties in the city, Huicheng District was at a moderate imbalance level, while Huiyang District, Longmen, Boluo and Huidong Counties were at a slight imbalance level. Results from the scenario analysis indicated that in order to improve the coordination between the transportation and tourism systems, decision makers in Huicheng and Huiyang Districts are supposed to increase effort to develop tourism while those in Longmen, Boluo and Huidong Counties are expected to pay more attention to transportation development. This research will help provide a decision-making basis for the urban planning in the Huizhou City. It will also provide a theoretical and methodological support for the other areas with similar concerns.

1. Introduction
With the rapid development of social economy and significant improvement of people’s living standards, the output value of travel industry in China has continuously increased in recent decades. Concurrently, transportation infrastructure has also been constantly improved. However, the development of transportation and tourism systems in many cities in China are incongruous, which have seriously restricted the sustainable development of social economy. Thus, it is necessary to scientifically describe the transportation status and its interaction with tourism development. Analysis of coupling relationship between transportation and tourism systems will help provide a decision-making basis for urban planning, which is of great importance to the regional management.

In recent years, there have been many quantitative research on the relationship between transportation and tourism systems. A considerable number of studies were conducted on the development of intelligent models and systems, which have been widely applied to many research areas in multiple spatial scales[1-2]. For example, an Intelligent Transport and Tourism System was proposed in Hadoop environment to provide information such as lodging facilities available and items to be purchased in a city in an efficient manner[1]. Also, the impact of a certain traffic form on tourism were investigated in some research[3-4]. A high speed rail way can reduce the transportation costs, which will further reinforce the spatial competition between tourism destinations[3]. In addition, transportation
service for tourism in some special areas, such as remote islands, congested tourism traffic corridors and new tourism towns, were analyzed in the previous research[5-7]. However, essential connection between the two systems and the subjective tendency of decision makers on the evaluation results of coupling relationship need to be further investigated, which are very important to the developing plan of tourism transportation.

In this research, coupling and coordination relationship between transportation and tourism systems will be explored based on the coupling and coordination degree model. Taking the Huizhou City as the study area, the temporal and spatial changes of the relationship between the two systems in the city were analyzed. Also, the subjective tendency of decision maker will be explored based on the evaluation results of coupling and coordination degree model. Thus, this research will provide some alternatives for the coupling optimization of tourism and transportation industries in the Huizhou City. Also, it can provide a theoretical support for the regional management of other areas with similar concerns. It is of great scientific and practical significance.

2. Methodology

2.1 Description of the coupling and coordination degree model

The coupling and coordination degree model was used in this research to evaluate the coupling coordination degree between transportation and tourism systems due to its advantages in interpreting the relationship between two or more systems[8]. The model framework is given as follows[9]:

\[ x_{ij}' = (x_{ij} - x_{min})(x_{max} - x_{min})^{-1} + 0.01 \]  
(1)

\[ p_{ij} = x_{ij}' \left( \sum_{i=1}^{m} x_{ij}' \right)^{-1} \]  
(2)

\[ h_{j} = -(ln m)^{-1} \sum_{i=1}^{m} p_{ij} \ln p_{ij} \]  
(3)

\[ w_{j} = (1 - h_{j}) \left( \sum_{j=1}^{n} (1 - h_{j}) \right)^{-1} \]  
(4)

\[ U = \sum_{j=1}^{n} w_{j} x_{ij}' \]  
(5)

\[ D = (C \times T)^{1/2} \]  
(6)

\[ C = \left( U_{1} \times U_{2} \right) \left( U_{1} + U_{2} \right)^{-2} \]  
(7)

\[ T = \alpha U_{1} + \beta U_{2} \]  
(8)

where, \( x_{ij} \) and \( x_{ij}' \) represent the original value and the standardized value of index \( j \) in year \( i \), respectively; \( x_{max} \) and \( x_{min} \) indicate the maximum and minimum value of index \( j \) among all years, respectively; \( p_{ij} \) denotes the proportion of the index \( j \) in year \( i \); \( h_{j} \) denotes the information entropy of the index \( j \); \( w_{j} \) denotes the weight of the index \( j \) by information entropy weight (IEW)[10]; \( n \) is the number of indexes, and \( m \) is the number of years; Suppose \( x_{ij}' \) represents the standardized index of transportation or tourism system. \( U \) is the comprehensive evaluation value of transportation or tourism system; \( D \) represents the coupling coordination degree, and \( D \in [0,1] \); \( C \) represents the coupling degree; \( U_{1} \) and \( U_{2} \) refer to the comprehensive evaluation value of transportation and tourism systems, respectively; \( T \) reflects the overall level of transportation and tourism systems; \( \alpha \) and \( \beta \) represent the contribution of transportation and tourism systems, respectively.

2.2 Establishment of the comprehensive evaluation index systems

Two sets of evaluation index systems were formed for transportation and tourism systems, respectively. Specifically, the transportation system contains 10 indicators including passenger traffic volume,
highway passenger traffic volume, turnover of passenger traffic, civil vehicles ownership, private vehicles ownership, number of passenger vehicles, length of highways on operation, cargo volume, highway freight volume and length of urban paved pavement. As for tourism system, there are 6 indicators in the evaluation index system, including total tourism revenue, revenue from domestic tourism, foreign exchange income from international tourism, number of tourist hotels, number of inbound overnight visitors and number of domestic overnight visitors. Concurrently, the coupling relationship between the transportation and tourism systems at both city and county levels will be discussed in this research. Due to the data availability and the inadequacy of the existing data statistical systems, some indicators will be deleted in the index systems established for county level evaluation. Specifically, only passenger traffic volume, turnover of passenger traffic, length of highways, highway density and cargo volume will be considered in the transportation system, while total number of visitors, total tourism revenue, number of visitors in A-grade scenic spots and operating income in A-grade scenic spots will be considered in tourism system.

2.3 Discriminating standard of the coupling coordination degree between transportation and tourism systems

In order to facilitate the analysis of the coordinated development stage between the two systems in each region, the values of coupling coordination degree are divided into the following four levels[11]: high imbalance (0 < D ≤ 0.2), moderate imbalance (0.2 < D ≤ 0.3), slight imbalance (0.3 < D ≤ 0.4), approaching imbalance (0.4 < D ≤ 0.5), reluctant coordination (0.5 < D ≤ 0.6), primary coordination (0.6 < D ≤ 0.7), intermediate coordination (0.7 < D ≤ 0.8) and high coordination (0.8 < D ≤ 1).

3. Case study

With an area of 11,599 km², Huizhou City is located in the east coast of Guangdong-Hong Kong-Macao Greater Bay Area. It is a new second-tier city with 5 counties, including Huicheng, Huiyang Districts, and Huidong, Boluo and Longmen Counties. The population of the city is approximately 4.83 million. By the end of 2018, the total length of highways in the Huizhou City was 14001 km. The annual cargo throughput of coastal ports was 74.53 million tons. The Pingtan Airport of the Huizhou City has 36 flights, connecting 31 cities. Until 2018, three trunk railways, one intercity railway, and one freight railway had been built in the Huizhou City. Also, there are two trunk railways under construction. The total number of tourists in 2018 was 58.9 million and the total tourism revenue was 50 billion Yuan. Although there are abundant tourist resources in Huizhou and the construction of transportation infrastructure is progressing steadily, the imbalance between regional transportation and tourism development still exists. Thus, it is very important to study the interrelation between the two systems. The relevant data of the indicators in this research were mainly obtained from the statistical yearbooks provided by the Bureau of Statistics, as well as the Culture and Tourism Bureau of the Huizhou City and each county. Years 2014 and 2015 were considered in this research.
4. Results and discussion

In order to analyze the subjective tendency of decision makers on the evaluation results of coupling relationship, scenario analysis method was used in this research. Specifically, three scenarios were set as follows. Scenario 1: the contribution of tourism to the coordinated coupling of the two systems is greater than that of transportation (assume \( \alpha = 0.4, \beta = 0.6 \)); Scenario 2: the contribution of transportation and tourism systems were supposed to be of the same importance (\( \alpha = \beta = 0.5 \)); and Scenario 3: the contribution of transportation to the coordinated coupling of the two systems is greater than that of tourism (assume \( \alpha = 0.6, \beta = 0.4 \)).

4.1 The overall coupling coordination degree between the transportation and tourism systems in the Huizhou City

The comprehensive evaluation values of the transportation and tourism systems (i.e., \( U_1 \) and \( U_2 \)) in the Huizhou City during 2014 and 2015 were both less than 0.2, indicating that there was still much room for the improvement in the development of the two systems (Table 1). The comprehensive evaluation values of the transportation system were slightly lower than those of tourism system. Therefore, as for the regional coupling coordination status of the Huizhou City during this period, the development of the transportation system was overall slightly lagged behind. In addition, the results of the scenario analysis showed that the coupling coordination degrees of the two systems in the Huizhou City reduced with the decreasing \( \beta \) values (i.e., contribution of tourism system). When the decision maker tends to pay more attention to the tourism system, the resulting coupling coordination degree will be higher.

| Years | \( U_1 \) | \( U_2 \) | \( C \) | Scenarios | \( D \) | Levels       |
|-------|--------|--------|------|----------|------|-------------|
| 2014  | 0.0791 | 0.1272 | 0.4862 | 1        | 0.2291 | Moderate imbalance |
|       |        |        |        | 2        | 0.2239 |             |
|       |        |        |        | 3        | 0.2186 |             |
|       |        |        |        | 1        | 0.2291 |             |
| 2015  | 0.0790 | 0.1272 | 0.4861 | 2        | 0.2239 | Moderate imbalance |
|       |        |        |        | 3        | 0.2186 |             |

4.2 Coupling and coordination degree of the transportation and tourism systems at the county level

During 2014 and 2015, the coupling coordination degrees between the transportation and tourism
systems in the counties were at a relatively slight imbalance level except for Huicheng District. The comprehensive evaluation values of the tourism system in Huicheng District were much lower than those in the other four counties (Tables 2 and 3). The comprehensive evaluation values of the transportation system in Huidong, Boluo and Longmen Counties were lower than those of the tourism system, indicating that the development of transportation in the three counties was slightly lagged behind. Although there were several newly built highways in 2015, which have had a positive impact on the regional connectivity, the development speed of the road-network was slow. Therefore the role of transportation in tourism was still limited. Concurrently, the results of the scenario analysis showed that the coupling coordination degrees between transportation and tourism systems in Huicheng and Huiyang Districts would reduce with the decreasing β values (figure 2). Thus, when the decision makers attach more importance to tourism system, the resulting coupling coordination degree between the two systems will be higher. Conversely, the coupling coordination degrees between the two systems in the Huidong, Boluo, and Longmen Counties would reduce with the decreasing α values (i.e., contribution of the transportation system). When the decision makers pay more attention to transportation system, the coupling coordination degree between the two systems in these three counties will be higher.

Table 2. Comprehensive evaluation value and coupling degrees between transportation and tourism systems at the county level.

| Districts       | 2014     | 2015     |       |       |       |       |       |       |
|-----------------|----------|----------|-------|-------|-------|-------|-------|-------|
|                 | 2014     | 2015     |       |       |       |       |       |       |
|                 | U1'      | U2'      | C     | U1'   | U2'   | C     |       |       |
| Huicheng District | 0.2133  | 0.1187   | 0.4793 | 0.2176 | 0.1243 | 0.4811 |       |       |
| Huiyang District | 0.1971  | 0.2279   | 0.4987 | 0.2186 | 0.2115 | 0.5000 |       |       |
| Huidong County  | 0.1982  | 0.2563   | 0.4959 | 0.2179 | 0.2748 | 0.4967 |       |       |
| Boluo County    | 0.1943  | 0.2422   | 0.4970 | 0.2144 | 0.2771 | 0.4959 |       |       |
| Longmen County  | 0.1944  | 0.2616   | 0.4945 | 0.2128 | 0.2759 | 0.4958 |       |       |

Table 3. Coupling coordination degrees and levels between transportation and tourism systems at the county level.

| Districts       | D (Levels) | D (Levels) |       |       |       |       |       |       |
|-----------------|------------|------------|-------|-------|-------|-------|-------|-------|
|                 | Scenario 1 | Scenario 2 | Scenario 3 |       |       | Scenario 1 | Scenario 2 | Scenario 3 |
| Huicheng District | 0.2739   | 0.2820  | 0.2900 | 0.2788 | 0.2868 | 0.2945 |       |       |
|                 | (Moderate imbalance) | (Moderate imbalance) | (Moderate imbalance) | (Moderate imbalance) | (Moderate imbalance) |       |       |
| Huiyang District | 0.3279   | 0.3255  | 0.3232 | 0.3273 | 0.3279 | 0.3284 |       |       |
|                 | (Slight imbalance) | (Slight imbalance) | (Slight imbalance) | (Slight imbalance) | (Slight imbalance) |       |       |
| Huidong County  | 0.3400   | 0.3357  | 0.3314 | 0.3538 | 0.3498 | 0.3457 |       |       |
|                 | (Slight imbalance) | (Slight imbalance) | (Slight imbalance) | (Slight imbalance) | (Slight imbalance) |       |       |
| Boluo County    | 0.3329   | 0.3293  | 0.3257 | 0.3536 | 0.3491 | 0.3446 |       |       |
|                 | (Slight imbalance) | (Slight imbalance) | (Slight imbalance) | (Slight imbalance) | (Slight imbalance) |       |       |
| Longmen County  | 0.3407   | 0.3358  | 0.3308 | 0.3525 | 0.3481 | 0.3435 |       |       |
|                 | (Slight imbalance) | (Slight imbalance) | (Slight imbalance) | (Slight imbalance) | (Slight imbalance) |       |       |
Figure 2. Coupling coordination degrees between transportation and tourism systems of the 5 counties in the Huizhou City.

5. Conclusions
In the context of national tourist transportation development, it is important to increase the level of coupling relationship between transportation and tourism systems. Taking the Huizhou City as the study area, the coupling coordination degree between the two systems during 2014 and 2015 were obtained based on the coupling coordination degree model. The results showed that the coupling coordination degrees between the two systems in the Huizhou City were at a moderate imbalance level. As for the coupling coordination degree of the two systems at the county level, the degrees in Huicheng District were at a moderate imbalance level, while those of Huiyang District, Longmen, Boluo and Huidong counties were at a slight imbalance level. The results of the scenario analysis showed that it is favorable to the coordination between the two systems in Huicheng and Huiyang Districts when the decision makers attach more importance to the tourism development. On the contrary, decision makers in Longmen, Boluo and Huidong counties are supposed to pay more attention to the development of transportation in order to enhance the coupling relationship between the two systems. This research will provide a decision-making basis for the regional management of tourist transportation development.

Acknowledgements
This work was financially supported by the National Key Research Program of China (Grant No. 2016YFC0502806), the National Natural Science Foundation of China (51809045 and 41801203), the Natural Science Foundation for Distinguished Young Scholars of Guangdong Province (No.2017A030306032), Guangdong Innovation Team Project for Colleges and Universities (No. 2016KCXTD023), GDUPS (2017), the Scientific Research Foundation for High-level Talents and Innovation Team in Dongguan University of Technology (No. KCYKYQD2016001).

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