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How Space and Time Influence Regional Linkage: A Study on the Mechanism of Central Collapse in the Tourism Development of the Chengdu-Chongqing Economic Circle

Encheng Wang, Hong Hui, Renjun Zhang *

Chongqing University of Technology, Chongqing, China

* **Corresponding author**: zrj@cqut.edu.cn

Abstract: The "central collapse" of tourism development reflects the uneven tourism development in dual-core or multi-core urban agglomerations. Understanding the spatiotemporal mechanisms behind its formation can help promote coordinated tourism development in urban agglomerations. The spatiotemporal distribution of tourism flows is a fundamental factor influencing tourism development in urban agglomerations. This study focuses on the Chengdu-Chongqing Economic Circle, constructing a multi-agent tourism flow micro-simulation model based on multi-source data. The model simulates tourist behavior under specific travel days, uses network node degree to analyze the distribution characteristics of tourism flow networks in the Chengdu-Chongqing region, and employs the rank-size rule to assess the impact of travel days on the spatial distribution balance of tourism flow. Finally, two indicators—scenic spot density and playtime density—are introduced to analyze the relationship between the distribution of tourism flows and the spatial distribution of scenic spots in Chengdu-Chongqing. The study finds that: (1) The tourism flow micro-simulation model developed in this paper can dynamically reflect spatiotemporal changes in tourism flow and analyze the spatiotemporal mechanisms behind "central collapse" in tourism development. This model can also serve as a virtual simulation platform for evaluating the applicability of regional tourism development decisions. (2) The increase in travel days promotes the expansion of the spatial distribution of tourism flow but also exacerbates the unevenness of regional tourism flow distribution. (3) There is a significant positive correlation between tourism flow distribution and scenic spot spatial distribution. Therefore, increasing the density of scenic spots in central Chengdu-Chongqing, particularly by enhancing the density of playtime, is key to retaining tourists.

Keywords: Chengdu-Chongqing Economic Circle; Central Collapse; Spatiotemporal Factors; Micro-Simulation of Tourism Flow; Multi-Agent Modeling.

1. Introduction

The Chengdu-Chongqing Economic Circle, located in the upper Yangtze River region, plays a crucial role in China's Western Development strategy. It promotes regional coordination, urban-rural integration, and economic prosperity. Although the tourism industry in this area has grown rapidly, a phenomenon known as "central collapse" has emerged, where central regions like Chengdu and Chongqing lag in tourism development compared to surrounding areas. This issue has been observed in other urban agglomerations such as the Chang-Zhu-Tan [1] and Beijing-Tianjin-Hebei regions [2].

"Central collapse" refers to the lag in development in central areas of dual-core or multi-core urban agglomerations [3]. In Chengdu-Chongqing, despite having high economic levels and tourism infrastructure, certain central areas (e.g., Dazu District) experience slower tourism growth compared to peripheral areas. This imbalance cannot be fully explained by factors like economic development, tourism resources, or transportation alone.

The spatial distribution of tourism flows plays a crucial role in this phenomenon. By analyzing how tourism flows are distributed across the region, we can better understand the causes of the "central collapse." This study aims to model tourism flow dynamics in the Chengdu-Chongqing Economic Circle, using a multi-agent simulation to explore how factors such as travel days, attraction density, and tourism resources contribute to the unbalanced tourism development. Through this approach, we aim to uncover the mechanisms behind the central collapse and provide insights for promoting more coordinated regional tourism development.

2. Research Area, Research Methods, and Data Sources

2.1. Overview of the Research Area

The Chengdu-Chongqing Economic Circle, located in the upper Yangtze River region, includes 113 districts in Sichuan and 27 in Chongqing, with Chengdu and Chongqing as its central cities. In recent years, tourism has rapidly developed, becoming a key driver of regional economic growth. In 2023, the region received 740 million tourists and generated over 750 billion yuan in tourism revenue. However, there are significant imbalances, particularly the "central collapse" phenomenon between Chengdu and Chongqing. This study focuses on the 142 districts and counties in the Chengdu-Chongqing region to explore this issue.

2.2. Research Methods

(1) Tourism Flow Micro-Simulation System Based on Multi-Agent Simulation: Multi-Agent Simulation (MAS) is used to model the interactions between multiple agents, suitable for studying dynamic, nonlinear tourism decision-

making problems like tourist number prediction and route planning. This study constructs a micro-simulation system based on MAS to simulate tourists' choices of attractions and paths. The system integrates Geographic Information System (GIS) and a relational database (RDBMS) to create the simulation environment and record tourist locations, revealing the "central collapse" phenomenon in Chengdu-Chongqing's tourism development.

(2) Geographic Information System (GIS): GIS is a tool for managing and analyzing spatial data. This study uses GIS to build a model for the Chengdu-Chongqing Economic Circle to analyze the distribution of tourism resources, transport networks, and tourist flow characteristics. ArcGIS software is used to preprocess road network data, perform path analysis, and visualize the simulation results.

(3) Network Node Degree Analysis: Node degree is a key indicator in network analysis, representing the number of connections to a node. In this study, Gephi software is used to calculate the out-degree, in-degree, and degree values of cities, reflecting their ability to attract tourists and influence surrounding areas.

(4) Rank-Size Model Analysis: Zipf's Law, applied widely in areas like city size and tourism, analyzes the distribution of tourism flow. This study uses Zipf's Law to examine how the tourism flow distribution follows a concentrated or more balanced pattern, based on the Zipf parameter (q).

2.3. Data Sources

(1) Tourist Travel Day Proportion: Data from the "2023 Douyin Tourism Content Experience Research" helps analyze tourists' travel day distribution.

(2) Attraction Information: Data from 4A/5A-level tourist attractions in the Chengdu-Chongqing region, sourced from the 2023 directory published by local cultural and tourism departments. This includes attraction names, levels, and visit durations from Baidu Maps.

(3) Reception Data for Distribution Nodes: Sourced from the "2019 National Economic and Social Development Statistical Bulletin" to estimate reception capacities.

(4) Road Network Data: From the "Shuijingzhu" road network, providing details on road types, speeds, and locations.

3. Chengdu-Chongqing Tourism Flow Micro-Simulation Model Construction

3.1. Simulation Model Logical Framework

The tourism flow micro-simulation model is represented by agents, where each agent represents a tourist (or a group of tourists). The simulation process primarily includes three parts: setting the attributes of tourists and the environment (attractions, distribution nodes, and transportation network), simulating tourist activities, and calculating and analyzing tourist states. During the simulation of tourist activities, the determination of tourism routes is influenced by the attributes of tourists and the environment, tourists' preferences for attractions, and path selection rules. After tourists decide on their travel routes, the system will calculate and record in detail the spatial movement trajectory of each tourist.

3.2. Simulation Conditions Setup

(1) Tourist and Environmental Attributes： The initial conditions for the simulation include the setup of tourist initial states, attraction states, distribution node states, and transportation network conditions. The tourist agent’s attributes include the starting point (either an attraction or distribution node), planned travel days, random start time, and planned visit duration at attractions. Attractions have a visit duration, chosen based on Baidu Maps. Distribution nodes have a reception capacity, and the transportation network is based on actual road conditions (type, length, and speed).

(2) Route Selection Rules: The basic behavior rule of the tourist agent is under the condition that time allows, the tourist will prioritize visiting attractions they are more interested in. To effectively simulate the randomness in tourists' travel decisions due to factors such as traffic congestion and costs, the following algorithm is used to implement this rule: 1) Each tourist has a preference table for attractions. 2) When time allows, the probability that a tourist chooses to visit a particular attraction is proportional to the tourist's preference for that attraction.

3.3. Tourism Route Selection Algorithm

3.3.1. Attraction Preference Setting

A tourist's attraction preferences are influenced by factors like income, culture, and the quality and cost-effectiveness of attractions. To simplify simulation, this study assumes tourists prefer attractions with higher recognition, often reflected in more reviews. The probability of an attraction being chosen is based on its number of reviews, with more reviews increasing its selection likelihood. The system calculates the selection probability for each attraction, ensuring the total probability for all attractions equals 1. Tourists' top-choice attractions are determined by these probabilities, followed by ranking additional attractions until all are selected.

3.3.2. Tourism Route Determination

This study models tourist route selection based on existing destination choice models. Tourists first select the top-ranked attraction based on their preferences. If the planned travel time is insufficient, the system selects the next available attraction. The process repeats until the tourist’s planned time is exhausted. Once all selected attractions are determined, the system calculates the route and selects distribution nodes based on capacity, finalizing the tourist’s travel route.

3.4. Simulation Results Recording and Analysis

The simulation records tourist agents' movement from the starting point, visiting attractions in sequence, and concluding at the distribution node. It tracks the tourist's location and state at each time point. The results are analyzed through a real-time database, visualizing tourist flow distribution at each attraction for better understanding.

3.5. Simulation Model Validation

The simulation model undergoes two types of validation: reliability and validity. Reliability is tested by adjusting parameters like travel days, ensuring the model functions as expected. Validity is tested by comparing simulated results with actual tourist data using Pearson's correlation coefficient, showing a moderate positive correlation (0.623).

4. The Spatiotemporal Mechanism Behind the Formation of "Central Collapse" in Tourism Development in the Chengdu-Chongqing Economic Circle

4.1. Experimental Hypotheses

Regional tourism development differences stem from the spatiotemporal distribution of tourism flows, influenced by factors like travel days, visit duration, and attraction density. Longer travel days promote broader exploration, while shorter trips concentrate tourism in certain areas. This study tests two hypotheses: travel days and attraction duration significantly impact tourism flow distribution.

4.2. Analysis of the Impact of Tourist Travel Days on the Balance of Tourism Flow Distribution

To ensure an adequate sample size and minimize errors, 1,000 tourist agents are used in each simulation, repeated three times to average the results. Two experimental scenarios are set: a Mixed Travel Days Distribution Simulation based on the "2023 Douyin Tourism Content Experience Research" and a Specific Travel Days Distribution Simulation (1-12 days). Gephi software analyzes the tourism flow network in each scenario, showing that as travel days increase, the network shifts from centralization to decentralization. The tourism flow becomes more spread out, with core cities like Chengdu and Chongqing remaining hubs, but with more connections to peripheral areas.

The Zipf parameter (q) indicates an unbalanced tourism flow in the Chengdu-Chongqing region. As travel days increase, the imbalance becomes more pronounced. For trips lasting 1-7 days, tourism flow is relatively regular, but for longer trips, the complexity increases, with more concentration at popular attractions, worsening the imbalance.

Table 1. Zipf Parameter and Determination Coefficient for the Rank-Size Rule of Tourism Development in Districts and Counties of the Chengdu-Chongqing Economic Circle

Simulation	Fitting Formula	Zipf Parameter (q)	Determination Coefficient (R^2)
mixed	Y=-1.81636X+9.97000	1.81636	0.96787
1day	Y=-1.33677X+7.41907	1.33677	0.94215
2days	Y=-1.63577X+8.74575	1.63577	0.95720
3days	Y=-1.76544X+9.48103	1.76544	0.96629
4days	Y=-1.91943X+10.37701	1.91943	0.96983
5days	Y=-2.04144X+11.14127	2.04144	0.95008
6days	Y=-2.1203X+11.70321	2.12030	0.92660
7days	Y=-2.18442X+12.1408	2.18442	0.90491
8days	Y=-2.22995X+12.47007	2.22995	0.89058
9days	Y=-2.27872X+12.80271	2.27872	0.86347
10days	Y=-2.26872X+12.91562	2.26872	0.85394
11days	Y=-2.29172X+13.1395	2.29172	0.82811
12days	Y=-2.24893X+13.14592	2.29172	0.81439

4.3. Analysis of the Impact of Attraction Play Duration and Its Spatial Distribution Density on the Balance of Tourism Flow Distribution

The number of attractions and the duration of visits are key factors influencing tourist distribution in the Chengdu-Chongqing Economic Circle. This study focuses on attraction density, attraction play duration density, and tourist density by district, using Pearson's correlation coefficient to analyze their relationships.

Attraction density refers to the number of attractions per square kilometer, while attraction play duration density measures the total visit time of attractions per square kilometer. Tourist density reflects the number of tourists per square kilometer in each district. These values are calculated from data sources such as Baidu Maps, ArcGIS, and the simulation results.

The results reveal a strong positive correlation between attraction quantity density and tourist density (Pearson's coefficient = 0.6515), indicating that areas with more attractions, such as the central districts of Chengdu and Chongqing, also attract more tourists. Conversely, areas with fewer attractions, like the central collapse area, have lower tourist density.

Similarly, the correlation between attraction play duration density and tourist density is also significant (Pearson's coefficient = 0.6342). This shows that regions with both a high density of attractions and longer average visit durations per attraction attract more tourists. Areas with lower play duration density tend to have sparser tourist flows.

These findings highlight that both the number of attractions and their play duration are crucial factors in attracting tourists. High-density attraction areas tend to concentrate tourist flows, becoming key hubs in the regional tourism network.

5. Conclusion and Discussion

This study systematically analyzes the "central collapse" phenomenon and its formation mechanism in the tourism development of the Chengdu-Chongqing Economic Circle by constructing a tourism flow micro-simulation model based on multi-agent systems. The model integrates multiple data sources such as tourist travel days, attraction play duration, and transportation network data. By simulating the behavior and decision-making process of tourist agents, the model accurately reproduces the tourism flow and distribution under different travel days and attraction resource configurations. The model covers key aspects such as tourist destination

selection, play path planning, and time distribution at attractions. It dynamically reflects the spatial and temporal variations of tourism flow and has passed reliability and validity tests. This model can not only be used to explore the causes of tourism regional polarization but also be applied to regional tourism flow forecasting and intervention, serving as a virtual simulation platform for decision support.

Through multi-scenario simulations, the model effectively reveals the role of spatiotemporal factors in regional linkage and deeply analyzes the formation mechanism of the "central collapse" phenomenon, providing a scientific basis for regional tourism collaborative development. Specific findings include:

Impact of Tourist Travel Days on the Chengdu-Chongqing Tourism Flow Network Structure: As the number of travel days increases, the spatial range of tourism flows gradually expands. However, the resource attraction of Chengdu and Chongqing and their network dominance are further strengthened, leading to more noticeable regional development polarization. Short-term travelers are mainly concentrated in Chengdu, Chongqing, and their surrounding areas, while medium- and long-term travelers expand to more distant areas, although Chengdu and Chongqing remain dominant.

Impact of Attraction Density and Play Duration Density on Tourist Distribution: Both attraction density (Ds) and play duration density (Dt) have a significant positive correlation with tourist density (Dv). This study introduces attraction play duration density (Dt) as a key indicator of tourism resource attractiveness, and combines it with attraction density (Ds) to systematically analyze their dual impact on tourist density (Dv). The introduction of this innovative indicator not only enriches the theoretical framework of regional tourism development but also provides a more detailed perspective for understanding tourist behavior and tourism flow dynamics.

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