# Postprint: Evolution of Ningxia Tourism Flow Network Structure Under COVID-19

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## Abstract

Investigating the evolution characteristics of tourism flow network structure under the impact of COVID-19 is conducive to discovering new tourism routes and identifying new demands in the tourism market. Based on online travelogues and from the perspective of COVID-19' s impact on tourism flows, this study employs social network analysis methods to investigate the evolution of Ningxia' s tourism flow network structure before and after the pandemic. The results indicate that: after the pandemic, new tourism nodes and routes have improved the uneven distribution of nodes in Ningxia' s tourism flow network; COVID-19 has increased the likelihood of tourists traveling from peripheral area nodes to other peripheral area nodes, altering the agglomeration and diffusion effects of tourism flow network nodes within peripheral areas; COVID-19 has dramatically changed the positions of religious venues and performance-type core tourism nodes within the network structure, with some even disappearing from the entire tourism flow network structure; however, the vast majority of core tourism nodes have demonstrated strong competitive advantages both before and after the pandemic.

## Full Text

### Structural Evolution of Tourism Flow Network in Ningxia Under the Influence of COVID-19

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**Abstract:** Investigating the evolutionary characteristics of tourism flow network structures under the impact of COVID-19 facilitates the discovery of new tourism routes and identification of emerging market demands. Based on online travelogues and from the perspective of pandemic effects on tourism flows, this study employs social network analysis to examine the structural evolution of Ningxia's tourism flow network before and after COVID-19. The results indicate that post-pandemic emergence of new tourism nodes and routes has modestly improved the uneven distribution of network nodes in Ningxia. COVID-19 has increased the likelihood of tourists traveling between peripheral nodes, altering the agglomeration and diffusion effects within marginal areas. The pandemic has substantially changed the positions of religious venues and performance-based core tourism nodes within the network structure, with some disappearing entirely, though most core nodes have maintained strong competitive advantages throughout the pandemic period.

**Keywords:** COVID-19; tourism flow; network structure; online travelogues; Ningxia

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### 1.1 Study Area Overview

Ningxia Hui Autonomous Region (hereinafter referred to as Ningxia) is located in the inland northwest of China, characterized by a temperate continental climate and a total area of 6.64$×10^{4}$ km$^2$. Known as the "Jiangnan beyond the Great Wall," Ningxia boasts abundant natural and cultural resources despite its modest size, featuring striking landscapes where the Yellow River, deserts, grasslands, forests, rice paddies, and the Great Wall converge. The region serves as a confluence of Yellow River culture, Western Xia culture, and frontier fortress culture, providing unique advantages for tourism development. Since its designation as China' s second provincial-level comprehensive tourism demonstration zone in September 2016, Ningxia's tourism economy has achieved considerable growth, though challenges remain, including uneven distribution of tourism resources and imbalanced development levels across prefecture-level cities.

### 1.2 Research Methods

Social network analysis is a quantitative research method applied in social sciences that focuses on relationships between actors rather than their individual attributes. This approach can reflect network characteristics from both node-level and overall perspectives, making it an optimal paradigm for tourism flow network research. This study employs social network analysis to investigate Ningxia' s tourism flow network structure, using centrality and structural holes to examine individual node evolution before and after COVID-19, and network density, core-periphery structure, and cohesive subgroups to analyze overall network evolution.

### 1.3 Data Sources and Processing

The research data primarily comprise publicly available online travelogues posted by tourists. To ensure comprehensive data collection, multiple renowned travel service platforms were selected, including Ctrip, Mafengwo, Qunar, Fliggy, and Tuniu. Travelogues published between 2019 and 2021 were collected as the data source for analyzing tourism flows before and after the pandemic. The data collection focused on tourist attractions but was not limited to them; frequently mentioned sites such as Lanshan Park and South Gate Square were also included and collectively termed "tourism nodes" alongside formal attractions.

The data processing procedure involved six steps: First, web crawler technology was used to obtain 2,860 online travelogues about Ningxia from various platforms. Second, manual verification was conducted to eliminate data with obvious commercial advertising, severe information deficiency, or unclear spatiotemporal displacement, resulting in 2,156 valid travelogues. Third, different names for the same node and hierarchical relationships between nodes were standardized. Fourth, to ensure statistical significance and simplify analysis, tourism nodes with word frequency greater than 10 were extracted as network nodes, and a weighted directed multi-value relationship matrix was constructed according to the order of mention in travelogues. Fifth, after repeated testing, a breakpoint value of 3 was selected to dichotomize the multi-value relationship matrix (values $ $3 indicated a connection, while values <3 indicated no direct connection; it must be noted that in reality these nodes may not be completely unrelated, but their connections were not captured due to data collection limitations). Sixth, UCINET software was used for indicator analysis and processing, and Gephi software was employed to visualize Ningxia' s tourism flow network structure for 2019 and 2021 [Figure 1: see original paper].

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## 2 Analysis of Tourism Flow Network Structure Evolution

### 2.1.1 Node Centrality Analysis

**Degree Centrality** reflects a node' s aggregation and radiation capacity within the network. In directed networks, it is divided into out-degree and in-degree centrality (higher out-degree indicates stronger radiation capacity, while higher in-degree indicates stronger aggregation capacity). The degree centrality analysis reveals large variances in both in-degree and out-degree for 2019 and 2021, indicating persistent imbalance in node distribution. However, the variance decreased post-pandemic, suggesting modest improvement in distribution equity, likely due to pandemic-related capacity restrictions that dispersed tourist flows and enabled more nodes to gain visibility. Comparing the 2019 and 2021 data shows that Shapotou, Zhenbeibu Western Film Studio, Western Xia Imperial Tombs, Shuidonggou, and Shahu consistently exhibited high in-degree and out-degree values, demonstrating strong capacity to attract and disperse tourists

throughout the pandemic. These nodes are primarily Ningxia' s few 5A-level attractions with high 知名度, making them preferred destinations.

**Closeness Centrality** measures a node' s connectivity with others; higher values indicate more central network positions and less susceptibility to other nodes' influence. In directed networks, it comprises outward and inward closeness centrality (higher outward closeness indicates greater convenience for tourists traveling from the node to others, while higher inward closeness indicates easier access from other nodes). Comparison of 2019 and 2021 data reveals that Shapotou, Zhenbeibu Western Film Studio, Western Xia Imperial Tombs, Shahu, Shuidonggou, and Ningxia Museum maintained high inward and outward closeness centrality, indicating tight connections with other nodes and strong accessibility across different tourism routes.

**Betweenness Centrality** reflects a node' s control over others; higher betweenness indicates stronger control capacity, while lower values suggest greater dependency. The betweenness analysis shows large variances for both years, indicating significant differences in nodes' intermediary roles. Shapotou' s betweenness value far exceeds other nodes before and after COVID-19, primarily due to its central-western location connecting north and south Ningxia, serving as a crucial hub with significant locational advantages and minimal pandemic impact. Additionally, Zhenbeibu Western Film Studio, Western Xia Imperial Tombs, Shahu, Shuidonggou, and Helan Mountain Rock Art maintained high betweenness, demonstrating strong control over surrounding nodes and serving as important transfer points. Notably, post-pandemic betweenness increased for non-core nodes such as Zhihui Yuanshi Winery and Yellow River Hostel, likely because the pandemic slowed overall travel pace, increased local tourism, and reduced dependency on core nodes.

### 2.1.2 Structural Holes Analysis

Structural holes reflect the competitiveness of tourism nodes within the network, measured by effectiveness, efficiency, and constraint. Higher effectiveness and efficiency with lower constraint indicate stronger competitiveness. The structural holes analysis shows that Shapotou, Zhenbeibu Western Film Studio, and Western Xia Imperial Tombs maintained high effectiveness and low constraint throughout the pandemic, indicating high structural holes levels and significant competitive advantages derived from unique natural and cultural characteristics that the pandemic could not undermine. Additionally, Yellow River Hostel, Zhihui Yuanshi Winery, and Zhangyu Mosel Fifteenth Generation Winery exhibited decreased constraint values post-pandemic, suggesting enhanced competitiveness. This likely resulted from pandemic-induced shifts of outbound tourists to domestic markets, attracting visitors to these internationally-styled nodes.

### 2.2.1 Network Density Analysis

Network density measures the overall connectivity among tourism nodes; higher density indicates better network effectiveness. In both 2019 and 2021, the actual number of connections was far below the theoretical maximum, with low network density values indicating loosely connected nodes. Post-pandemic density decreased further because, although new nodes emerged, their actual new connections were fewer than theoretically possible. This paradoxically reduced overall density despite network expansion.

### 2.2.2 Core-Periphery Analysis

Core-periphery analysis reveals each node' s position within the network structure. The analysis shows distinct core-periphery structures in both periods, with significant changes post-pandemic. Core nodes such as Nanguan Mosque and Shapotou Gala disappeared from the core after COVID-19, primarily due to pandemic policies suspending religious gatherings and performance activities. Meanwhile, non-scenic nodes like Beichangtan, Highway No. 66, and Yellow River Hostel gained prominence, reflecting enhanced demand for lifestyle-oriented leisure tourism. Additionally, cultural tourism nodes such as Guyuan Museum and Yinchuan Museum of Contemporary Art emerged in the core, indicating rising cultural tourism interest. Notably, the density of connections from periphery to core decreased more than periphery-to-periphery connections, suggesting increased likelihood of tourists traveling between peripheral nodes and reduced dependency on core nodes.

### 2.2.3 Cohesive Subgroup Analysis

Cohesive subgroups identify closely connected actor sets, revealing inter-subgroup and intra-subgroup connections to determine which nodes are frequently combined in itineraries. Comparison of subgroup structures [Figure 2: see original paper] shows no significant change in total subgroup numbers post-pandemic, but substantial reorganization occurred. Most nodes from original subgroups were recombined into new Subgroup 1, increasing its size and indicating tighter connections among these nodes in post-pandemic itineraries. Additionally, Subgroup 4 contains many nodes that emerged after COVID-19, forming new cohesive subgroups whose internal route combinations have expanded Ningxia' s tourism flow network structure and improved node distribution imbalance.

## 2.3 Tourism Flow Network Structure Evolution Trends

**Node Evolution Trends:** Post-pandemic emergence of new cultural, ecological, and characteristic town nodes (e.g., Yinchuan Museum of Contemporary Art, Dawukou North Wudang Ecological Tourism Zone, Helan Mountain Manpu Town) contrasted with the disappearance of religious and performance nodes (e.g., Nanguan Mosque, Shapotou Gala). Changes in node flows indicate

increased possibilities for peripheral-to-peripheral travel, significantly altering agglomeration and diffusion effects within marginal areas and creating opportunities for peripheral nodes.

**Overall Network Structure Evolution:** The emergence of new nodes and shifting tourist preferences have led to network structure improvements. However, because actual new connections remain below theoretical potential, overall network density has paradoxically decreased—a phenomenon expected to reverse as more nodes and routes become established. Combined with local government' s comprehensive tourism spatial planning, Ningxia' s tourism flow network structure will continue optimizing.

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## 3 Conclusions and Recommendations

Based on online travelogues and social network analysis, this study constructed Ningxia' s tourism flow network structure before and after COVID-19, analyzing evolution from both node and overall perspectives. The findings and recommendations are as follows:

1. **Overall Network Structure:** The pandemic has improved the tourism flow network structure through new nodes and routes, but optimization remains a systematic process requiring multi-stakeholder participation. Tourism enterprises should promptly identify new market demands, optimize product combinations, and enhance service quality, while local governments must improve top-level planning, public service infrastructure, and provide special funding support.
2. **Core Nodes:** COVID-19 reduced visitor flows to core nodes and eliminated some from the network structure, yet most core nodes maintained strong competitive advantages. As primary destinations for most tourists regardless of external changes, these nodes must continuously deepen resource advantages, enhance quality, and maintain strong brand images to preserve their core positions.
3. **Peripheral Nodes:** Increased peripheral-to-peripheral travel has substantially altered agglomeration and diffusion effects in marginal areas, creating development opportunities. These nodes should target lifestyle leisure and cultural tourism demands, accurately identify market segments, and seize opportunities by improving infrastructure and diversifying products to stand out in local tourism development.

**Research Limitations:** This analysis focuses primarily on COVID-19' s impact, though other factors also influence network evolution. Future research should adopt multi-angle, multi-factor approaches. Additionally, data collection limitations may have omitted some nodes and routes; future studies should broaden data sources through questionnaires, trajectory data, and other channels for more comprehensive analysis.

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*Note: Figure translations are in progress. See original paper for figures.*